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Smart Specialisation and Blue biotechnology in Europe

Mathieu Doussineau
Ales Gnamus
Javier Gomez
Silke Haarich
Frank Holstein

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Joint Research Centre

EUR 30521 EN

Contacts:
Name: Mathieu Doussineau
Email: mathieu.doussineau@ec.europa.eu

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Contents

Abstract

In May 2019, DG MARE and the JRC published its Blue economy Report. The main focus was on boosting a "blue" economy, the sustainable use of ocean resources for economic growth, through entrepreneurship, investment, and research and innovation. In order to better understand and illustrate the new opportunities coming from the Blue economy, this report introduces the emergent sector of Blue biotechnology. As one part of the larger Biotechnology sector, dedicated to marine bioresources, it is difficult to clearly define the sector. However, experts agree on the important value of the Blue biotechnology a) to make the existing sector of aquaculture and macroalgae harvesting more efficient and sustainable, and b) to develop new biological products and applications from marine bioresources with uses in energy, cosmetics, nutrition, health or manufacturing. 12 countries and 53 regions in the EU present linkages to the Blue biotechnology in their Smart Specialisation Strategies. A comprehensive screening of EU supported interventions in the current 2014-2020 funding period showed that € 238.6 million of EU funds have been invested in 182 projects and initiatives related to Blue biotechnology with a total budget of EUR 336 million. Smart Specialisation Strategies are a policy instrument which favour the discovery of innovation potential, also in the Blue biotechnology.

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Authors

Mathieu Doussineau, European Commission, Joint Research Center, Seville, Spain

Ales Gnamus, European Commission, Joint Research Center, Seville, Spain

Javier Gomez, European Commission, Joint Research Center, Seville, Spain

Silke Haarich, Spatial Foresight GmbH

Franck Holstein, Spatial Foresight GmbH

Executive summary

Innovation policy framework

As part of the EU Cohesion Policy, Smart Specialisation has contributed to discover and exploit innovation potential of EU regions and Member States, based on territorial specificities. This approach has also facilitated the identification of priorities for investment in research and innovation, as well as the mobilisation of innovation actors from public administrations, businesses, research organisations and universities, and the civil society.

The relevance of identifying these smart priorities goes beyond Cohesion Policy. Innovation niches emerge in maritime and coastal contexts creating opportunities for blue sustainable growth. Key elements which characterise smart specialisation can contribute to the improvement of EU Maritime Policy, particularly: the place-based approach addressing both local dimension and international cooperation; multilevel governance aiming at leaving no one behind; promotion of multi-stakeholder dialogue focused on envisaging and agreeing territorial vision and action.

Main outcomes

This science for policy report evidences the great potential of the Smart Specialisation approach applied in the context of maritime-oriented policies. Specifically, the report analyses the blue emerging sectors of aquaculture, algae and micro-algae, confirming that marine technology offers innovation potential being a multidisciplinary, knowledge and capital intensive technology.

Territorially, although Blue biotechnology offers major potential in coastal regions, it is observed that non-coastal EU regions also specialise in micro-algae and development of bioactive compounds from marine bio-resources. Accordingly, five different types of regional specialisation profiles were identified, reflecting the territorial and socio-economic diversity of EU regions.

Finally, the analysis remarks the capital importance of implementing monitoring mechanisms of economic activity in blue emerging sectors. In particular, this report elaborates on potential ways of measuring blue economy by identifying five indicators addressing: natural resources, policy, science and technology, business activity and social impact.

Avenues for action

Both the promising potential of blue emerging sectors, and the challenges derived from availability of data and information, suggest concrete avenues for action. First, stakeholders of EU Cohesion and Maritime policy can identify and concretise operational synergies thanks to the Smart Specialisation approach; this avenue may entail policy dialogues, peer reviews and any other activities leading to enable knowledge exchange from practitioners of both policies. Second, emerging sectors of blue economy should be understood and tackled as part of a comprehensive system. Thus, in the co-existence of emerging and consolidated sectors, there should be ground for identifying lessons learnt applied to the contexts of data acquisition, monitoring and evaluation. The suggested indicators can serve as starting point. Third, in the current global policy agenda based on sustainable development, further analysis should holistically integrate the social, economic and sustainable dimensions of blue growth. Accordingly, Smart Specialisation is well positioned to contribute highlighting its place-based innovation character along with its capacity to integrate stakeholders' vision.

1 Introduction

A sustainable future requires a healthy ocean and the sustainable use of marine resources. The scientific community and numerous technology-based start-ups in Europe and in other continents are still developing the scientific knowledge base and technology to fully explore and understand the ocean and the effect of human activities. Understanding better the activities and opportunities of Blue biotechnology, is a key prerequisite for preparing for the forthcoming UN Decade of Ocean Science for Sustainable Development (2021-2030). At the European level, the EU is currently negotiating whether to fund a Mission on Healthy Oceans, Seas, Coastal and Inland Waters within the context of the next Framework Programme for Research and Innovation Horizon Europe.

The European Commission is supporting the development of marine-related economic and innovation activities, in particular since the Communication on Blue Growth was adopted in 2011, showing how Europe's coasts, seas and oceans have the potential to be a major source of new jobs and growth. The so-called Blue Growth Strategy was presented by the Commission in 2012, followed by a number of initiatives and a first stock-taking report in 2017. In May 2019, DG MARE and the JRC presented the Blue Economy Report. The main focus was on boosting a "blue" economy, the sustainable use of ocean resources for economic growth, through entrepreneurship, investment, and research and innovation. This report focuses on Blue biotechnology as one of the emergent sectors in the Blue Economy.

In order to understand the emergent sector of Blue biotechnology, this report introduces the basic features of the sector and presents the status of ongoing innovative activities in Europe. As one part of the larger Biotechnology sector, dedicated to marine bioresources, it is difficult to clearly define the sector by the usual classification of business activities. However, experts agree on the important value of the Blue biotechnology a) to make the existing sector of aquaculture and macro-algae harvesting more efficient and sustainable, and b) to find new biological products and applications from marine bioresources in other sectors, including energy, cosmetics, nutrition, health and manufacturing.

Smart Specialisation Strategies are a policy instrument which favour the discovery of innovation potential. With regard to this report, they are an important source of information when analysing on-going innovation activities. This report analyses the variety of regional activities in Europe targeting the Blue biotechnology. Information stems from all national and regional Smart Specialisation Strategies and from national/regional and EU projects on innovation in aquaculture and marine biotechnology.

The report starts after this introduction with an overview on the Blue biotechnology Sector and its relevant subsectors. The next section describes the distribution of relevant marine biotechnology activities in European regions and relevant Sea Basins. The fourth section analyses the funding and investments in Blue biotechnology in Europe. The fifth section introduces into the challenges to describe the impact of the sector with commonly accepted indicators, given the lack of a statistical definition. New indicators to describe the activities in Blue biotechnology in EU regions are proposed. Finally, section 6 features case studies to show some regional approaches to research and innovation on Blue biotechnology. In the Annex, literature references have been included.

2 The Blue biotechnology area, setting the scene

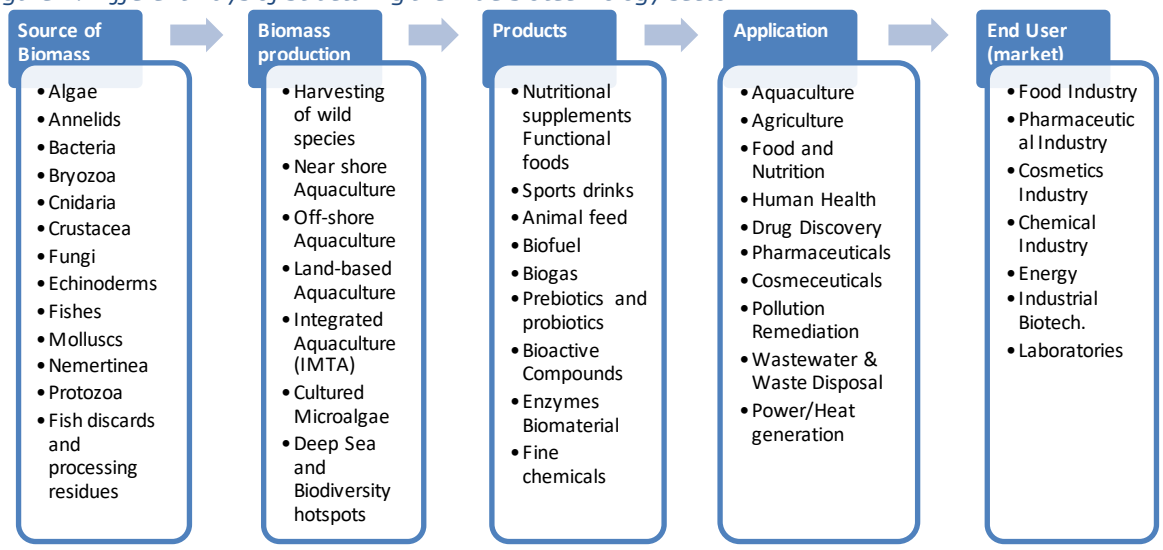
Blue biotechnology is biotechnology using vegetal and animal aquatic organisms. Blue biotechnology can be described as the exploration and application of biological products (whole organisms, cells, genes) from aquatic environments to create useful products for different markets including medicine/health, food, cosmetics, aquaculture, energy and environment. Blue biotechnology has the potential to address major global challenges such as sustainable food supplies, human health, energy security and environmental remediation, and to make a significant contribution to green growth in many industrial sectors (OECD, 2016).

Within the overall Blue Economy, today the Biotechnology plays still only a minor but a rather promising role. As enabling technology, it is still in an infant stage but is expected to be crucial for the development of new products and applications in many different industrial sectors. The European Commission's blue growth strategy identifies five sectors that have a high potential for sustainable jobs and growth, such as aquaculture, coastal tourism, marine biotechnology, ocean energy and seabed mining.

Blue biotechnology is a multi-disciplinary, knowledge and capital-intensive technology. The starting point or input to the process of extracting value from aquatic bio-resources is the culture and harvesting of available biomass. Aquatic biomass comprises many forms, including e.g. whole fish, discards from wild harvest or processing, aquaculture products, macro-algae — both wild and cultivated, micro-algae, marine invertebrates and micro-organisms (Hurst et al., 2016).

Currently, fish and macro-algae are the main sources of aquatic biomass used in commercial applications, principally as food and nutritional supplements. Other products are emerging, e.g. the use of bioactive compounds produced from algae and aquatic plants in cosmetics, biofuel or as food additives. Many other potential business activities are in a research stage and cover a wide range of applications for aquatic organisms that can be used as pharmaceuticals, enzymes and fine chemicals (Hurst et al. 2016). Blue biotechnology covers a complex network of activities linked to research and product development. Depending on the perspective, the sector can be structured differently.

Figure 1: Different ways of structuring the Blue biotechnology sector



Source: Own elaboration

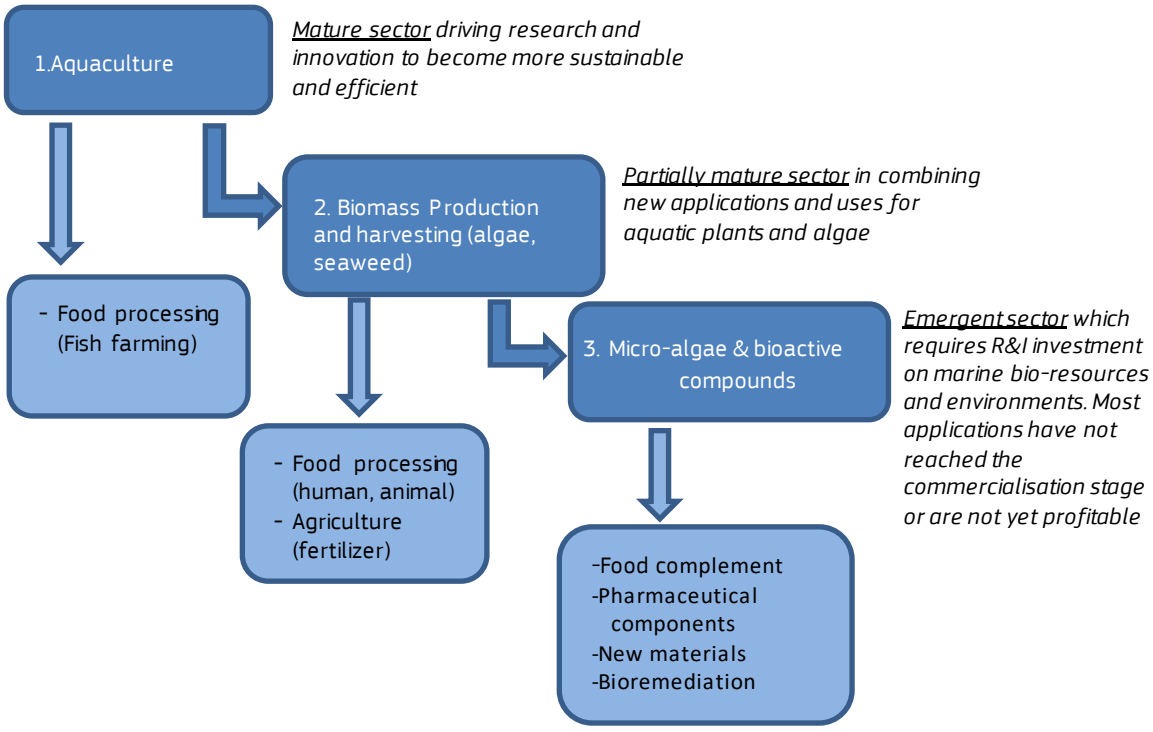
One characteristic feature of the Blue biotechnology value chain is that the core activities, by definition, cover early steps, reaching from discovery and cultivation of biomass to prototype and product development, while later stages and commercialisation are covered by other sectors, e.g. industrial

biotechnology manufacturing or industrial sectors. "*Subsequent stages or processes within the value chain become part of the wider biotechnology industry; these are separated from the marine component and should no longer be considered part of the Blue biotechnology sector per se, but rather as part of any of the other classical biotechnology.*" (Collins et al. 2018, ECORYS 2014)

This means that the Blue biotechnology sector is research-intensive and driven by innovative activities carried out by innovative SMEs, smaller service companies and research infrastructure, but with relatively low involvement of large companies.

Therefore, **three domains with different levels of maturity and characteristics** can be differentiated. The three areas are strongly intertwined and benefit mutually from progress in research on marine species. That is why they are not presented as classic economic subsectors but rather as fields of activity within the Blue biotechnology with different associated business models and in diverse technological stages. The fields of aquaculture and algae/seaweed are more centred in the first two phases of the value chain, related to biomass (Figure 2), while the field of microalgae and biorefinery is concentrated in the phases 3 and 4 of the value chain (innovation & development). However, for all activities and fields presented below, all phases of the value chain are important to get to new Blue biotechnology products and services.

Figure 2 The 3 sectors of Blue biotechnology



Source: own elaboration

2.1 Aquaculture

Definition

Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Aquaculture is an established and mature sector, originating from traditional activities like oyster breeding in France or Carp pounds in Poland. Aquaculture has developed rapidly over the last 50 years and is the fastest growing primary production sector worldwide (FAO 2018).

Marine aquaculture accounts for about one-half of total global aquaculture production. It can roughly be divided by species into four groups; finfish, crustaceans, molluscs and aquatic plants, with a relevant production in Europe only of finfish and molluscs. The EU aquaculture sector can be divided into three main sectors: Marine finfish, Shellfish and Freshwater finfish production. The marine sector is the most important economically and generated the largest turnover of € 2 731 million, followed by the shellfish sector with EUR 1 134 million and the freshwater sector with € 1 028 million (STECF - Scientific, Technical and Economic Committee for Fisheries, 2018).

Benchmark and geographical distribution

Europe has a small size of production compared to the global production and, in particular, to Asia. Its more prominent role in marine finfish cultures is largely dominated by the Norwegian salmon production. Aquaculture production in the EU is mainly concentrated in five countries: Spain (21%), France (15%), Italy (14%), the United Kingdom (14%), and Greece (10%), making up 74% of the sales volume. These five countries are furthermore covering 74% of the production in EU28 (STECF-18-19, 2018). In terms of value, United Kingdom is the largest contributor in EU with 21% of the total, followed by France (16%), Spain (13%), Greece (12%) and Italy (11%). These five countries combine 73% of the total EU aquaculture value (STECF-18-19, 2018).

Prospective and challenges

While the marine aquaculture sector can be considered an established industry in many parts of Europe, it is gaining over the last years ever more importance compared to sea fisheries. As an important share of Blue biotechnology research is targeting the aquaculture production, we consider it, for the sake of this report, an important driver of marine biotechnology research and a sub-sector of the Blue biotechnology.

Source: Horizon 2020 AquaSpace project (633476)

Many challenges can be associated to aquaculture such as low economic efficiency of traditional production systems, increased need for sustainable feed, animal and ecosystem health and environmental effects. In 2013, the European Commission published the Strategic Guidelines, four priority areas to boost the EU aquaculture sector identifying: (i) reducing administrative burdens, (ii) improving access to space and water, (iii) increasing competitiveness and (iv) exploiting competitive advantages due to high quality, health and environmental standards (European Commission, COM(2013) 229 final) . An increasing demand for cultivated finfish, shellfish and other marine products, asks for focused research and development and a paradigm shift towards more sustainable production (Costa Pierce 2010). New production methods like offshore (open ocean) aquaculture or integrated multi-trophic aquaculture (IMTA) also require biotechnology research and support. In this sense, aquaculture is a main driver and field of application of marine biological research and biotechnology. In 2014-2015, EU countries developed their Multiannual National Strategic Plans for promoting sustainable aquaculture [1], proposing concrete actions to address these strategic priorities and forecast of production growth. In these Multiannual National Strategic Plans, MS projected 25% growth in the EU aquaculture sector.

2.2 Biomass production: Algae and aquatic plants

Definition

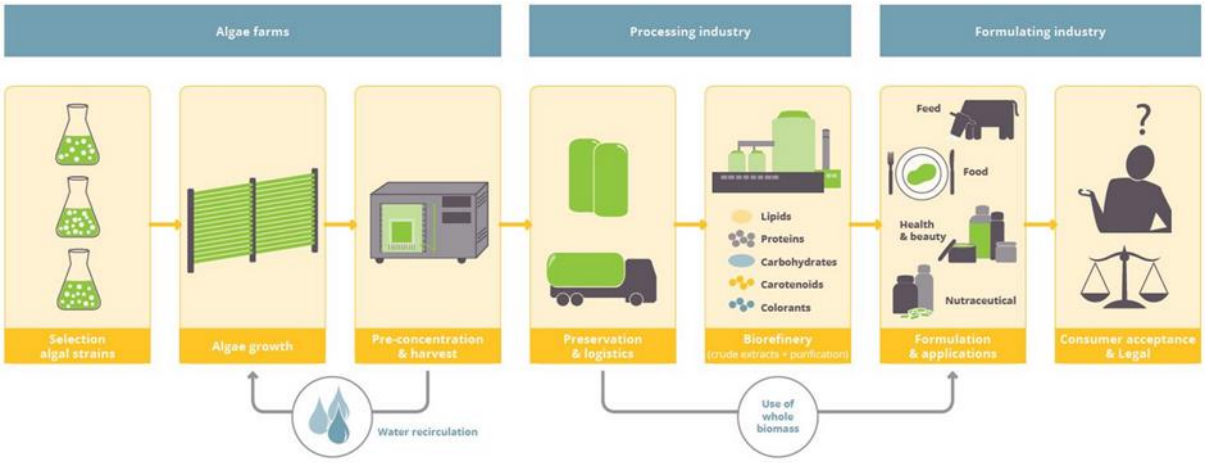
One emerging field of aquaculture is the cultivation of algae and aquatic plants. On the European Atlantic coast, macroalgae have been harvested by coastal populations for a long time. Two main uses were identified: human consumption and agriculture (cattle food and soil enrichment) (EUMOFA, 2019).

Aquatic plants can be used as human nutrition but also valorised through refining as animal feed, fuel source, fibres, co-digestion substrate, source of fatty acids, compost and organic fertilizers, antioxidants,

[1] https://ec.europa.eu/fisheries/cfp/aquaculture/multiannual-national-plans_en

colour, and plant disease control agents. In addition, they can be used for cleaning or metal uptake from wastewater streams (de Visser and van Ree, 2017).

Figure 3 Implementation and development of algae-based value chains



Source: Implementation and development of economic viable algae-based value chains (IDEA project 2017-2020)-Interreg North-West Europe

Benchmark and geographical distribution

The production of aquatic plants and seaweed (macroalgae) is an important activity in Asia, in particular, in China and Indonesia, producing together more than 25 million tonnes in 2016. Production in Europe, much smaller, does not reach relevant commercial volumes. Global production of farmed aquatic plants, overwhelmingly dominated by seaweeds, grew in output volume from 13.5 million tonnes in 1995 to just over 30 million tonnes in 2016 (FAO, 2018).

Of the 30 million tonnes of farmed seaweeds produced in 2016, some species are produced (mostly in East and Southeast Asia) almost exclusively for direct human consumption, although low-grade products and scraps from processing factories are used for other purposes, including feed for abalone culture.

EU production amounted to more than 93.000 tonnes in 2016, providing approximately 0,3 % of the world supply. The European seaweed processing industry is divided into two main categories: production of alginic acid (or alginate, see next section) and productions for agriculture (fertilizer and animal feed). Industries often settle close to seaweed harvesting areas. France (63% of EU production, almost exclusively brown algae) and Ireland (32%, almost exclusively brown algae) are the main producers. Other important EU producers are Spain (2,3%, mostly red algae) and Italy (1,3%, green and red algae). From 2005 to 2014, EU algae production increased 67%, with a peak reached in 2013 at 104.000 tonnes. (Araújo R, et al, 2019).

Perspectives and challenges

The algae aquaculture production, although still small for most of the EU-28 countries, is an expanding sector boosted in the recent years by the increase in the demand of algae biomass for a variety of applications (e.g. food, nutraceuticals, cosmetics, biomaterials, bioremediation).. However, with biogenetic research, new fields of application and new business opportunities emerge. These are linked mainly to the analysis and refinery of macro-algae or phytoplankton (microalgae).

2.3 Microalgae and bioactive compounds

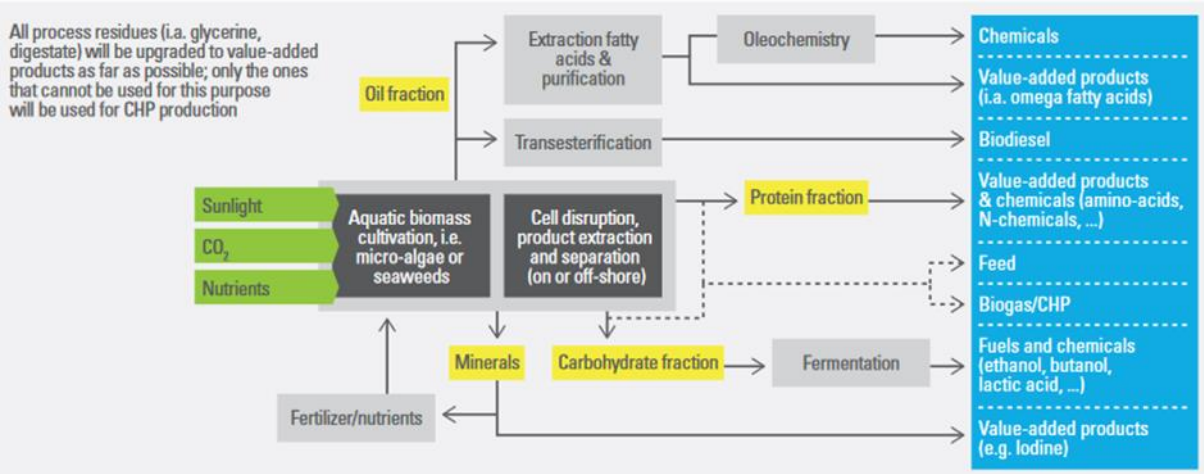
Definition

This sector is closely intertwined with other forms of algae and aquatic plant production. However, the subsector of microalgae and bioactive compounds is much more linked to basic genetic and biochemical research. In fact, microalgae production can take place in race ponds and not necessarily needs the open sea or the coast. Much more relevant for the generation of added value products is the related biotechnology research.

Even if some algae products like agar, alganic acids (or alginates) are already established in the market, most commercial applications of microalgae products and derived bioactive compounds are still in the product development or commercialisation phase. Microalgae are known to be sources of pigments, lipids, including omega-3 fatty acids, vitamins, toxins and other chemicals.

In most of the cases, "biorefinery" processes are necessary to transform the micro-organisms and to add value to biomass. After the initial discovery and research/experimentation phase, the product development phase is often extensive and specific to the biotechnology or industrial sub-sector for which an application is intended. Once a product has reached the stage of up-scaling and commercialisation, the 'blue' component diminishes and stakeholders are no longer limited to marine biotechnology but are part of other biotechnology or industry sectors (ECORYS, 2014). That means that in many cases the final product is no longer considered a product of the Blue biotechnology sector, but rather of the sector of application (food, cosmetics, pharmaceutical etc.). This is an important challenge for the identification and recognition of mature Blue biotechnology products.

Figure 4 Schematic diagram of an aquatic (marine) biorefinery



Source: EU FP7 Star-COLIBRI Project (241535)

Benchmark and geographical distribution

With regard to micro-algae, FAO recorded 89 000 tonnes of farmed microalgae from 11 countries in 2016 and more than 85% of the production come from China and Indonesia. In Europe the production of aquatic plants is emerging only recently. The algae aquaculture production is an expanding sector boosted in the recent years by the increase in the demand of algae biomass for a variety of applications such as food complements, nutraceuticals, cosmetics, biomaterials, bioremediation (FAO, 2018).

It can be assumed that microalgae biomass production in Europe does not reach important commercial volumes. Microalgae biomass production in Europe includes several species that are commercialized as raw biomass to be used for research or cultivation purposes or processed to several applications such as food (human nutrition), aquaculture feed, cosmetics and pharmaceuticals. Many countries produce microalgae but mostly at small-scale and in test installations (e.g. Denmark, France, Ireland, The Netherlands, Portugal, France, Germany, Italy, Spain etc.). The distribution of microalgae production sites in Europe shows a totally different pattern compared to the aquaculture and macro-algae distribution. Production sites are much more spread over different countries that have not been among the main producers of fish or seaweed, including Germany, Austria and Czech Republic. At the same time, production sites seem to locate not only at the coast, but also in capital cities, e.g. Rome, Paris, Berlin (Araújo et al., 2019).

This indicates that the production of bioactive compounds, even if based on aquatic biomass, is more and more disconnected from the maritime environment and much more related to relevant research capacities.

Markets and end users

Products based on marine bioactive compounds and microalgae can be classified as follows:

- **Products for human nutrition** are the most developed so far. Many forms of algae and product opportunities are currently under research and development e.g. for the production of algal oils (replacing fish oils), production of algal proteins for animal and human feeding, nutritional and pharmaceutical uses, residual proteins and carotenoid anti-oxidants, and high-energy oils for biofuels. There is still a growing demand and the hype of the so-called 'super foods' adds to good predictions for algae food products in the near future.

- **Biofuel** even if products are still in the development phase as the production costs are still quite high. There are some investments in micro-algal production in bioreactors for biofuel production.

- **Healthcare** is considered the biggest and most rapidly growing end-use sector for marine biotechnology through the extraction of bioactive compounds. Therefore, research is moving from biofuels towards biochemical compounds such as omega-3 fatty acids, algal protein and algal carbohydrates. Microalgae produce a suite of biochemical molecules, including carbohydrates, proteins, lipids, and nucleic acids, as well as essential vitamins and minerals. Marine organisms have developed unique metabolic and physiological capabilities that ensure survival in diverse habitats and have resulted in the evolution of an array of secondary metabolites. Several compounds have been developed commercially, with many others in preclinical and clinical development.

- **Water remediation** can be used for cleaning or metal uptake from wastewater streams**.**

Perspectives and challenges

The supply of high-value algal products is challenged by the overall costs of production, including cultivation systems and maintenance, limited culture productivity, and the biorefining processes. Despite the challenges of large-scale cultivation, there is a growing demand for micro-algal ingredients in foods, supplements, and potential pharmaceuticals. However, much more research is needed in this field to characterize the biochemical content of candidate microalgae to fully understand their benefits and possible concerns (Barkia et al. 2019).

One of the most promising outcomes of the Blue biotechnology research is the discovery of marine natural products (MNPs), defined as bioactive compounds derived from marine organisms. Microalgae biotechnology is a growing domain in this field, and recently there is a wide interest in exploring and exploiting micro-algal properties for the identification and characterization of new MNPs (Lauritano et al, 2019). The number of potential MNPs isolated now exceeds 28,000, with hundreds of new compounds being discovered every year, with 1490 of these new compounds recorded in 2017 alone (Carroll et al. 2019). For the production of relevant bioactive compounds not only microalgae can be used, but rather any microorganism from marine biomass such as macro-algae, aquatic plants and animals, fishery by-products or residues from aquaculture or transformation.

3 Blue biotechnology in EU regions

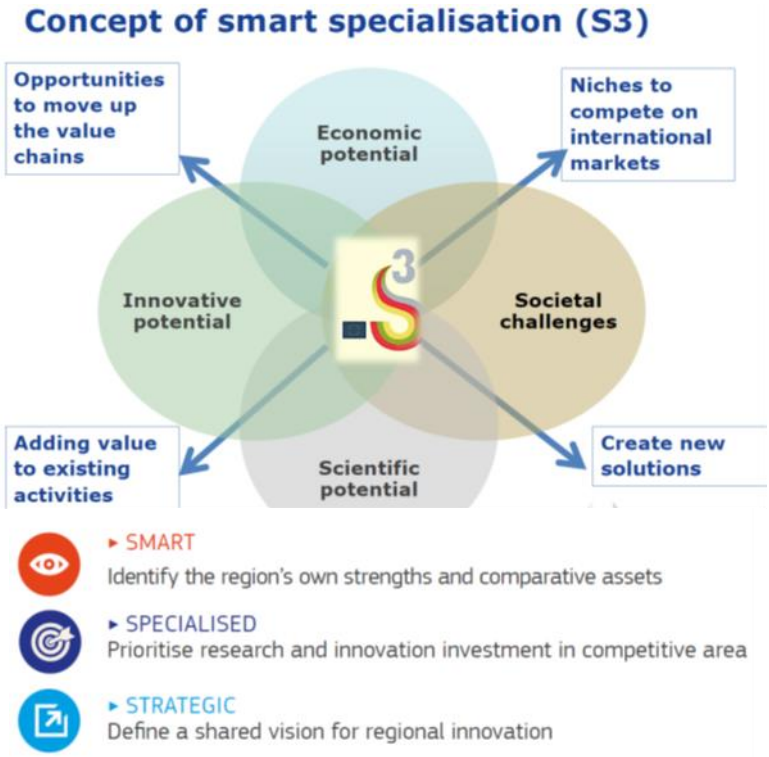
As described in the previous section, Blue biotechnology can represent a domain with high potential for growth in the EU Blue bioeconomy. Similarly to other emergent sectors, the development of Blue biotechnology should be monitored and measured by considering economic, sustainable and societal angles. Territorial aspects also appear as a fundamental tool to approach and understand precedent, current and future developments of this promising sector of the Blue economy. Accordingly, this session aims at highlighting the relevance of place-based innovation approaches as strategic policy driver to support Blue biotechnology development. In line with the main objective of this report, particular emphasis is given to how the Smart Specialisation Strategies for Innovation can identify and encourage Blue biotechnology action at local level. This allows a characterisation of at least five different profiles of regions supporting Blue biotechnology.

3.1 Blue biotechnology in Smart Specialisation Strategies

Taking into account that Smart Specialisation Strategies (S3) are implemented in the context of the EU Cohesion Policy and also understanding that some stakeholders of maritime policy may not be familiar with the S3 approach, here some key aspects of Smart Specialisation from both policy and scientific points of view:

Box 1 What is Smart Specialisation?

Smart Specialisation is an innovative policy approach that aims to boost growth and jobs at subnational level. It enables the identification and development of competitive advantages by concentrating efforts and resources in the identification of innovation niches. Smart Specialisation advocates for the conjugation of economic, innovative and scientific potential of a territory aiming to give response to societal challenges (see figure below).



Key characteristics of Smart Specialisation are, among others, the place-based approach which emphasizes the territorial aspects and its linkages with innovation discovery; the bottom-up character nurtured by an inclusive dialogue among local authorities, academia, business spheres and civil society; the identification of investment priorities based on local assets and resources and also the flexibility of the mechanism allowing improvements, modifications or reassessments all over the intervention process.

Origin and policy context

As part of the EU Cohesion Policy, the Smart Specialisation approach is relevant to all three priorities of Europe 2020: smart, sustainable and inclusive growth. First, Smart Specialisation can enable smart policy progress for the future of Europe as the development of an economy based on knowledge and innovation remains a fundamental challenge. Second, Smart Specialisation is relevant to achieve sustainable growth as innovation efforts and investments are required to shift towards a resource-efficient and low carbon economy, offering opportunities in domestic and global markets. Third, Smart Specialisation contributes to inclusive growth between and within regions by strengthening territorial cohesion and by managing structural change, creating economic opportunity and investing in skills development, better jobs and social innovation.
In the European Union, over the past five years more than 120 Smart Specialisation Strategies have been designed and implemented by Member States and regions. Financially, these strategies have been supported with more than € 67 billion available under the European Regional Development Fund (ERDF), together with national and regional funding. Smart Specialisation promotes interregional and cross-border partnerships in areas such as marine renewable energy, industrial modernisation and agri-food. Expected achievements by 2020 include bringing 15,000 new products to market and creating 140,000 new start-ups and 350,000 new jobs.

More information : https://s3platform.jrc.ec.europa.eu/what-is-smart-specialisation-

The Smart Specialisation Strategies (S3) are an important tool for regions to prepare strategic research and innovation activities, using a participative approach and involving relevant actors (researchers, investors, business community, policymakers). Even if they are not built on sectors but rather on technologies applied to relevant economic subsectors, they can be used to find out the regional priorities in research and innovation, for example, on the Blue Bioeconomy/Biotechnology.

As a first approach to the Blue biotechnology in Smart Specialisation Strategies, the Eye@RIS3 database[2] has been reviewed, focussing on topics related to "Marine Biotechnology", "Blue Growth", "Sea and Oceans", "Fishing and Aquaculture". This selection of keywords provides an overview of regions interested in research and innovation in the field of Blue biotechnology and Aquaculture. Moreover, complementary searches indicate that there are more regions with an access to Blue biotechnology, but probably hidden behind an approach concentrating on the fields of agri-food, new chemicals/plastics or advanced manufacturing (meaning the biorefinery processes).

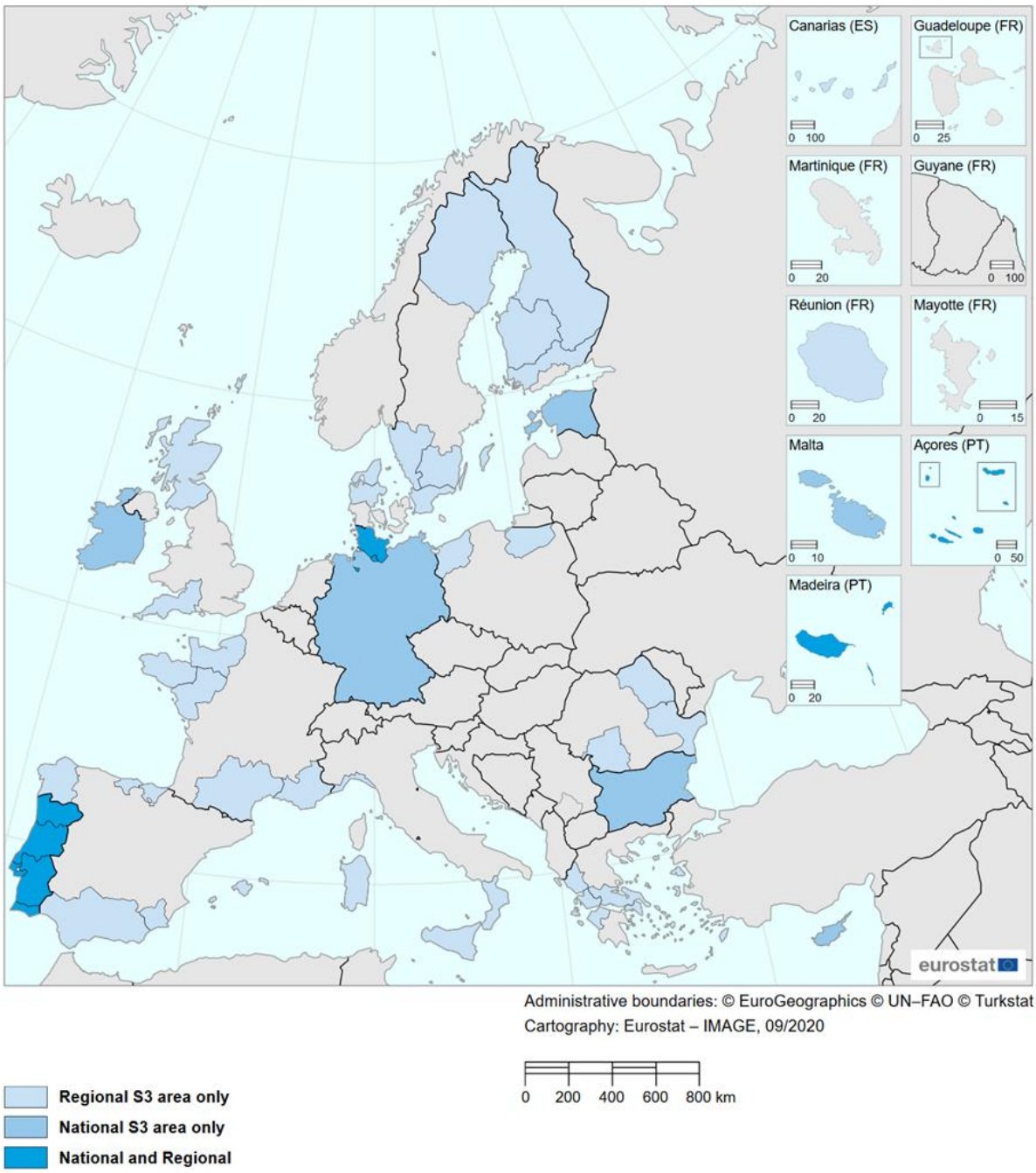
The analysis of the different features of the bioeconomy in European regions[3] also showed an important interest across Europe in developing the bioeconomy over the next years. Partially, this applies also to the Blue biotechnology, in particular, for regions who traditionally have access to marine resources and aquatic biomass. However, the analysis also showed a wide variety of drivers, of bioeconomy sectors and subsectors, of regional capacities and maturity and of approaches to deploy the bioeconomy. Nevertheless, a pattern of regional bioeconomy profiles became visible that can also be applied to the Blue biotechnology sector.

Similarly, the regional interest on Blue biotechnology research & innovation activities would be understood, a priori, by the distribution and availability of marine and aquatic resources. However, Blue biotechnology activities are also identified in non-coastal regions – mostly linked to the development of micro-algae and the development of bioactive compounds from marine bio-resources.

The analysis of approaches to support the Blue biotechnology in Smart Specialisation strategies shows that there are different regional configurations dealing with the Blue biotechnology. The following section characterises the observed profiles of EU regions specialised in Blue biotechnology.

[2] https://s3platform.jrc.ec.europa.eu/map
[3] Spatial Foresight et al. (2017)

Figure 5 EU Regions and Countries with a Blue bioeconomy focus in their S3 Strategies



Source: Own elaboration and based on Eye@RIS3

3.2 Regional specialisation profiles

According to the analysis mentioned in the previous section, EU regions' degree of specialisation can be characterized in five different profiles in function of research orientation, availability of natural resources, value chain, industrial activity and holistic view of blue bioeconomy. More specifically, the five profiles are described as follows:

1. Regions with a research driven bioeconomy profile. The profile covers Regions hosting important research institutions dealing with Biotechnology research in general and, among others, investigate on marine bioresources. Some of these institutions may be not located near Sea. The activities are research driven and search for applications of the research results across all sectors

and in other industries This profile concerns, for instance, some German, Finnish or Dutch regions and Flanders (BE) having a more research-driven approach to Blue biotechnology.

2. Regions with a natural resources and heritage driven bioeconomy profile. The profile covers more traditional sector of the bioeconomy. The business focus is, so far, mainly on fisheries, traditional aquaculture and tourism. Research and innovation on the Blue biotechnology focuses on making existing aquaculture and fishing more sustainable, understanding better the marine environment and the state of the existing bioresources. This includes basic research on marine ecosystems, biological monitoring and mapping of bioresources as well as analysis of threats to the marine environment. The protection of the marine environment is the main driver to Blue biotechnology research. This profile fits to many regions in the Mediterranean or at the Black Sea, and, in particular, islands, have a huge potential and many marine resources, however, they are not yet economically exploited.

3. Regions with a primary value chain bioeconomy profile. –Research and innovation are still is mostly applied to existing activities and focussing on the agricultural and food/feed use of marine resources, e.g. to incrementally make aquaculture sustainable and integrated, to analyse the use of waste streams (shellfish, fishing) as feed for aquaculture or to examine the capacity of new species in fishery or aquaculture. The existing fisheries and aquaculture industries are the main driver for Blue biotechnology research. Research on new and different applications of marine bioresources (nutrition, cosmetics, pharmaceutical) is still incipient and has a low technological intensity. This profile corresponds to Regions like Galicia (ES), Crete (EL) or many Danish or Portuguese regions have a strong fishery and aquaculture sector.

4. Regions with an industrial biotech profile. Regions covered by this profile support research on biorefining, using different kinds of biomass (including microalgae), even if they may not have access to the Sea or traditional marine activities. The focus of these regions is predominantly on industrial uses of marine bioresources, mainly for energy, industrial biotechnology, and environmental technologies, but less on purely agricultural or feed applications. The interest in the Bioeconomy and in finding more integrated and circular models of industrial production are the main drivers to Blue biotechnology research. – Regions fitting to this profile are Sachsen-Anhalt (DE), Nord-Pas-de-Calais (FR), or Lombardia (IT) which have interest in bioactive compounds for industrial applications, among them the ones coming from aquatic and marine bioresources.

5. Regions with an integrated and advanced Blue Bioeconomy profile – The profile corresponds to regions having a holistic approaches to Bioeconomy, connecting biomass and traditional fishing with research and active business development on new applications of bio-based products for industry, food, energy, etc. Blue biotechnology research and innovation is most advanced and open to all possible applications for marine bioresources with different drivers that stimulate research and innovation on the Blue biotechnology (e.g. a long tradition in fisheries and aquaculture, strong research institutions and other industrial sectors that demand circular and more sustainable business models). These regions can be seen as models for a strategic approach to Blue biotechnology, e.g. Scotland (UK) or Brittany (FR).

The regional profile types are idealised types. However, in the real-world many regions show characteristics of 2 or 3 types combined. For example, the case of Scotland, presented below, combines features of Type 3 and Type 4. Schleswig-Holstein combines features of Types 1, 2 and 3. The case of Slovenia in the Mediterranean Sea combines Types 2 and 3.

3.3 Blue biotechnology in European Sea Basins

The development and uptake of the Blue biotechnology shows quite uneven patterns in the different European Sea basins. The following sub-sections describe key aspect of Blue biotechnology developments in 3 sea-basins: Atlantic, Baltic and Mediterranean. Besides the differences observed in macro-territorial configurations; the Blue biotechnology activity in these basins is also influenced by opportunities and

challenges derived from policy intervention, for example, supporting the creation of technological centres; facilitating the collaboration with peers of other basins through transnational cooperation projects, or aligning local – national and macro-regional policies to achieve common goals.

3.3.1 The Atlantic Sea basin[4]

The Atlantic Sea Basin is home to a rich diversity of algae species. Marine resources had so far been largely unexploited – apart from traditional uses as food or supplement – and there appears to be significant potential for the discovery of new added-value bio-products. Even if the Blue biotechnology is still in an infant stage, marine biotechnology activities are already underway looking for applications in almost all industry sectors (e.g. energy, healthcare, environmental bioremediation, cosmetics and food).

The Atlantic area hosts many Centres of Excellence in science, technology and innovation, has a solid reputation in the field of engineering, a stable political and governance system and a number of knowledge-based SMEs. Acknowledged Research Centres are located in Scotland (UK), The Netherlands, Flanders (BE), Brittany (FR), the Basque Country, Galicia (both ES), North Portugal, the Algarve, Azores (all three PT).

Projects such as NETALGAE (Interreg Atlantic Arc) or EnAlgae (Interreg North-West Europe) helped to develop a common understanding and important cooperation among key stakeholders. They offer important starting points for the development of pan-European networks.

Examples of the advanced level of activity among the Atlantic Sea countries are the following national or regional blue bioeconomy strategies or plans:

- Portugal: The Blue Bioeconomy Roadmap for Portugal was presented in 2019. It is the result of a joint work of CIIMAR, BLUEBIO ALLIANCE and Fundação Oceano Azul (Vasconcelos et al., 2019).
- Scotland: Aquaculture Science & Research Strategy. Produced on behalf of the Scottish Government Ministerial Group for Sustainable Aquaculture (MGSA). (2014).
- Ireland: Harnessing Our Ocean Wealth - An Integrated Marine Plan for Ireland (2012) and National Marine Research & Innovation Strategy 2017–2021 (2017).
- Spain: Strategic Plan for Innovation and Technological Development Fisheries and Aquaculture 2014 - 2020. PTEPA. Update 2017.

Box 2 Focus on the EnAlgae project

EnAlgae was a strategic initiative of the INTERREG IVB North West Europe programme, with activities taking place between 2011 and 2015. It brought together 19 partners and 14 observers across 7 EU Member States. The EnAlgae project developed sustainable technologies for micro and macro algae biomass production and assessed the potential for, and barriers to, their further development and commercialisation. The project assessed the potential for producing energy and fuels from both microalgae and macro algae.

The inventory of North-West European algae initiatives shows that most of the initiatives try to serve or aim at more than one market. A lot of initiatives are using waste stream to produce algae for one or more algae markets. Examples of waste streams include CO2, manure, and industrial or municipal wastes. As it saves money to use these waste streams, waste stream handling can be viewed as a market sector in its own right. The waste stream market and the energy market are the most frequently named and have the lowest added value. High value molecules form the top of the market in terms of added value from algal biomass and 26 initiatives are focussed on this market.

More information : http://www.enalgae.eu/

[4] See Collins et al. 2018

3.3.2. The Baltic Sea basin

The report on Blue Growth, Maritime Policy and the EU Strategy for the Baltic Sea Region (European Commission, 2013) identified the potential for Blue Growth in each country of the Baltic Sea Region (BSR) and at sea basin level. The study revealed that the Blue biotechnology industry in the region is still nascent and very much focused on R&D. Blue biotechnology has limited economic performance and plays only a small role in the development plans of the region. Denmark, Germany (in particular, Schleswig-Holstein) and, increasingly, Poland and Estonia pushing the most for the development of new marine bioproducts.

The Submariner project launched in 2010 on the Sustainable Uses of Baltic Marine Resources represents the start of strengthening institutional set-ups for transnational Blue biotechnology cooperation within the Baltic Sea area. At the end of the project in 2013, Submariner became a sustainable network[5] supported by EU Member States (and Russia). The network has published a roadmap "Towards a blue-green economy in the Baltic Sea Region" (Submariner, 2016). Another transnational initiative is the ScanBalt initiative. ScanBalt is a non-profit organisation composed of the health and bio economy communities in Denmark, Estonia, Finland, Iceland, Latvia, Lithuania, Norway, Poland, Sweden, northern Germany, northern Netherlands and north-western Russia. Scanbalt is acting as a think tank and business and innovation facilitator. Since the European Strategy for the Baltic Sea Region (EUSBSR) has promoted Bioeconomy area, several Interreg projects have been launched these last years under the umbrella of the submariner network:

- Baltic Blue biotechnology ALLIANCE (Interreg Baltic Sea Region)
- Baltic Blue Growth (Interreg Baltic Sea Region)
- InnoAquaTech (Interreg South Baltic)
- Smart Blue Regions (Interreg Baltic Sea Region)
- Blue Platform (capitalisation project Interreg Baltic Sea Region)

Apart from the EU Programmes, the Baltic Sea has also other funding instruments to promote research, innovation and cooperation in the field of Blue biotechnology, such as the BONUS programme or the Nordic Marine Innovation Program 2.0.

Box 3 Baltic Blue biotechnology Alliance

The Baltic Blue biotechnology Alliance is a consortium of research and technology institutes, technology parks and innovation companies. The partners bring together and can apply the knowledge to facilitate product development for entrepreneurial endeavours in Blue biotechnology. Also, together with Start-ups and SMEs (small and medium-sized enterprises, so-called "cases"), they have created a functional ecosystem of actors, that takes advantage from constantly evolving, demand-driven support within Blue biotechnology.

More information: https://www.submariner-network.eu/balticbluebioalliance

3.3.3. The Mediterranean Sea basin

The Mediterranean is regarded as one of the world's most important locations in terms of marine biodiversity, contributing between 4% and 18% of the World's marine species (Nike Bianchi & Morri,, 2000). No comprehensive regional strategy focusing specifically on marine biotechnology R&D yet exists within the Mediterranean Sea Basin. However, general marine science topics in this area may be studied by organisations such as CIESM or through projects like the SEAS-ERA scheme.

Spain, Italy and Greece are among the most dynamic countries with regard to Blue biotechnology development, but also Malta and Cyprus are active. However, compared to other sea basins, the general

[5] https://www.submariner-network.eu/

focus is more on applied research and finding solutions for environmental (or other) problems, rather than on basic research and the development of new added-value products.

The Mediterranean Blue Economy Stakeholder Platform (MedBESP)[6] – former Virtual Knowledge Centre – is a regional networking platform for sharing knowledge and for supporting the development of the blue economy.

In the eastern Mediterranean region, Blue Bioeconomy is driven as part of the Blue Growth objective of the EUSAIR[7]. The Initiative for the sustainable development of the Blue economy in the western Mediterranean region was adopted by the European Commission on 19 April 2017 and endorsed by the Council of the EU on 26 June 2017.

The WestMED initiative is the result of years of dialogue between ten countries in the western Mediterranean region involved in the '5+5 Dialogue': five EU Member States (France, Italy, Portugal, Spain and Malta), and five Southern partner countries (Algeria, Libya, Mauritania, Morocco and Tunisia). These countries are ready and willing to work together on their shared interests for the region: to increase maritime safety and security, promote sustainable blue growth and jobs, and preserve ecosystems and biodiversity.

A rather broad strategic guideline is given by the BLUEMED Strategic Research and Innovation Agenda promoted since 2015 by the European Commission, with one axis dedicated to "Innovative businesses based on marine bio-resources in the Mediterranean" (see also the case study later in this report).

Compared to the other sea basins, the sector seems to be less developed and also less connected across countries. Here lies a high potential for interregional and transnational cooperation.

Box 4 The Horizon 2020 BLUEMED Coordination and Support Action

Joint efforts of the Mediterranean countries, with the support of the European Commission, since early 2014 have resulted in the launch of the BLUEMED Strategic Research and Innovation Agenda (SRIA) in October 2015, calling for joint and aligned research and innovation strategies, programmes and activities related to the Mediterranean Sea. The BLUEMED Coordination and Support Action, a H2020 project to support the Initiative funded by the EC with almost € 3 million and under coordination of the Italian National Research Council and involving partners from Greece, Cyprus, Malta, Croatia, Spain, Slovenia, Portugal, and France, started in October 2016 aims primarily to fill the knowledge gap on Blue biotechnology among BLUEMED partners and seek active cooperation with other European networks such as EMBRC and Euro Marine.

Since 2017 the BLUEMED Initiative supports and facilitates cooperation and coordination not only among the EU Member States but also with the rest of the Mediterranean countries, in order to promote the alignment of programmes and pooling of resources and investments to address the challenges identified in the BLUEMED SRIA. Coordination with two relevant initiatives targeting the Mediterranean Basin, namely the WESTMED – Towards a Sustainable Blue Economy Initiative for the Western Mediterranean, and the EUSAIR – European Strategy for Adriatic-Ionian Region, is expected to enhance the efficiency of the actions, the investments in marine and maritime research, innovation and technology and to reduce fragmentation and duplication of efforts.

A crucial strength of the BLUEMED SRIA is that, similarly as in the smart specialisation concept, when implementing its goals, it addresses multilevel governance with a bottom-up and horizontal measures here also with a special focus on interregional and transnational cooperation. Its implementation plan allows for different types of actions to be undertaken at different levels with respect to geographical coverage, critical mass, joint funding, coordination of national/regional efforts or the use of EU instruments. BLUEMED identifies a set of challenges grouped in the three pillars and cross-cutting themes as follows:

- Key enabling knowledge for the Mediterranean >> Knowledge enablers
- Key sectoral enablers in the Mediterranean >> Economy enablers
- Enabling technology and capacity creation for the Mediterranean >> Technology enablers
- Cross-cutting enablers for Blue Jobs and Blue Growth

[6] http://www.medblueconomyplatform.org/vkc/news/#gsc.tab=0
[7] European Strategy for the Adriatic Ionian Region

4 Investments and support to the European Blue biotechnology sector

This chapter analyses the investments made by the EU to support research and innovation (R&I) in Blue biotechnology since 2014. Some reports anticipate that by 2026, Europe will be amongst the leading regions for Blue biotechnology significantly contributing to the global market. (Stratistics Market Research Consulting, 2018). Growing investments are being made in Blue biotechnology notably through the creation of small and medium sized enterprises, providing great contribution to the R&D leading the way in opening new markets for novel marine-based products. European Union supports a number of projects in marine biotechnology through the Horizon 2020 and its cohesion policy. However, the area of the Blue biotechnology is still rather small in the field of 'blue economy'. Given the relative emergent state of the area, the amount of public funding in research projects and the development of new products and services can be considered as low compared to others more traditional area such as Marine energy and Shipbuilding.

With regard to the EU Cohesion policy, the European Regional Development Fund (ERDF) and the European Maritime and Fisheries Fund (EMFF) represent the main sources of funding for R&I complementing the EU Research programme Horizon 2020. ERDF with the implementation of smart specialisation strategies provides support for Infrastructures & equipment, Technology transfer and, of course, direct support to R&I activities. In addition, the EMFF Operational Programmes support innovation and entrepreneurial development related to the fishery and aquaculture sector. DG MARE has created also a tool to promote investments for the Blue Economy, the BlueInvest platform[8] launched in 2019.

An analysis of EU funded projects concludes that, since 2014, around €262 million have been invested through ERDF and Horizon 2020 in projects supporting Blue biotechnology area (an estimation of €130 million through Horizon 2020 as of October 2019 and €132 million through ERDF as of December 2019). These figures should be considered as estimations only, as these are based on on-going programmes, embedded in more generic activities, not flagged as Blue biotechnology as such. Most Blue biotechnology projects are related to thematic areas such as life sciences, bio-economy, agri-food, new materials or bioenergy.
For the analysis, projects were collected through a keyword[9] search in projects' titles and abstracts in ERDF, Interreg and Horizon 2020 databases. The analysis includes fresh water and marine Blue Biotechnologies and focuses only on ERDF and Horizon 2020 programme, which are the two main sources of funding for the implementation of Smart specialisation strategies. Projects supported by EMFF were not considered in the analysis, due to lack of available information.

4.1 Similarities and differences between Horizon 2020 and ERDF support

Horizon 2020: strong increase between the FP7 and Horizon 2020

The EU has provided around €36 million under the FP7 Framework Programme (2007-2013) to fund Blue biotechnology projects and support measures (Submariner network, 2012). Horizon 2020 has shown an increasing budget for the field. Indeed, from 2014 to 2019, the Horizon 2020 programme has dedicated €130 million through 80 projects gathering 366 organisations established in Europe and beyond (e.g. USA, Canada, Israel). The average EU contribution per participation states at € 297 000 but with important disparities. The theme of blue biotechnologies is spread among various funding schemes and initiatives in the programme. Most of the large projects are supported by Bio-Based industries joint undertaking (BBI JU) and by Blue Growth dedicated calls for proposals. SME measures also represent a substantial share

[8] The BlueInvest platform supports investment readiness and access to finance for early-stage businesses, SMEs and scale-ups in the blue economy. https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1451
[9] Keywords used : algea OR alga* OR aquaculture AND biomass OR blue biotech OR seafood OR spirulin

of projects showing a deep interest from private sector. The Horizon 2020 programme supports 25 SME feasibility studies (SME support measures phase 1) each receiving a lump sum of 50,000 € witnessing the emerging side of the topic. On the other hand, some organisations are granted more than € 2.5 million for their participation in Research and innovation projects or SME measure phase 2 (scaling up projects). In terms of distribution between the public and private sector, the share of Horizon 2020 funding allocated to public research centres and universities states at 80% against only 20 % for large and small companies.

European regional Development Fund (ERDF): significant support to SMEs

Concerning the support given through EU Cohesion Policy, between 2014 and 2018 the ERDF supported 536 operations addressing Blue biotechnology. It represents an EU contribution of € 132 million to a total cost of € 171 million. The average operation states very close to Horizon 2020 one, at € 247 000. The collaboration between academic and the private sector is of crucial importance in this field revealing its emerging nature. Indeed, out of the € 132 million, 80 are allocated to technology transfer and university-enterprise cooperation primarily benefiting SMEs. Infrastructure and equipment represent only €11 million and pure R&I activities € 20 million. Almost 85% of ERDF funding addresses private companies, particularly SMEs (75%).

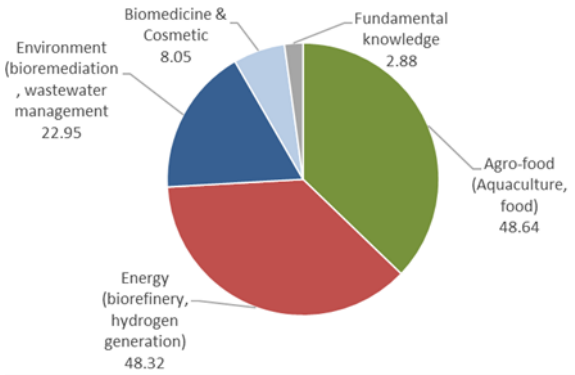
Within R&I activities dedicated to Blue Biotechnology, several areas can be distinguished as corresponding to the following target markets:

- Agri-food (aquaculture, food processing),
- Energy (biorefinery, hydrogen production)
- Environment protection (bioremediation, wastewater treatment)
- Biomedicine & Cosmetic
- Fundamental research (definition, process)

Again, an in-depth analysis of the projects shows similarities because all areas are covered by both funding sources but not with the same intensity. Project funded by Horizon 2020 show a more balanced distribution of funding among areas (Figure 66). Agri-food and energy areas receive the same amount followed by Environment protection. On the other hand, 72% of ERDF funding are dedicated to Agri-food and only 12% for Energy and 9% for Environment protection (Figure 77).

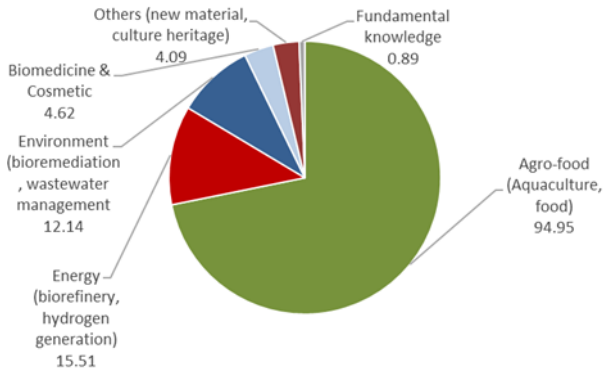
The difference between beneficiaries (Public and private organisations) can explain the different distribution of funding within areas. Synergies between the two EU funding sources are rather limited because not covering the same type of projects and not supporting the same beneficiaries. However, both programmes seem to play their role they are dedicated to complement each other.

Figure 6 Targeted areas in Horizon 2020 projects (in M€)



Source: Own elaboration

Figure 7 Targeted areas in ERDF funded projects (in M€)



Source : Own elaboration

4.2 Regional involvement in Blue biotechnology R&I projects

Horizon 2020: Strong participation of European coastal regions but not only

From a regional perspective, coastal regions are logically more represented (Figure 8). Almost all the regions of the Iberia peninsula are involved particularly Catalonia, Andalusia, Algarve and North Portugal For the rest of Europe, it is worth noticing that western and southern France (Brittany and Occitanie), North of the UK (Northern Scotland), part of Belgium, the Netherland, Denmark and Sweden are actively present in H2020 projects related to Blue Biotech.

However even if a vast majority of participating regions have access to the sea, some inland regions appear as important stakeholders also. Paris and Madrid regions, as well as Lombardy (Northern Italy) and the Karlsruhe regions (Baden Wurttemberg) count as important key players in Blue biotechnologies.

ERDF funding: "Usual suspects" and unexpected central and eastern European regions active in fresh water blue biotechnologies

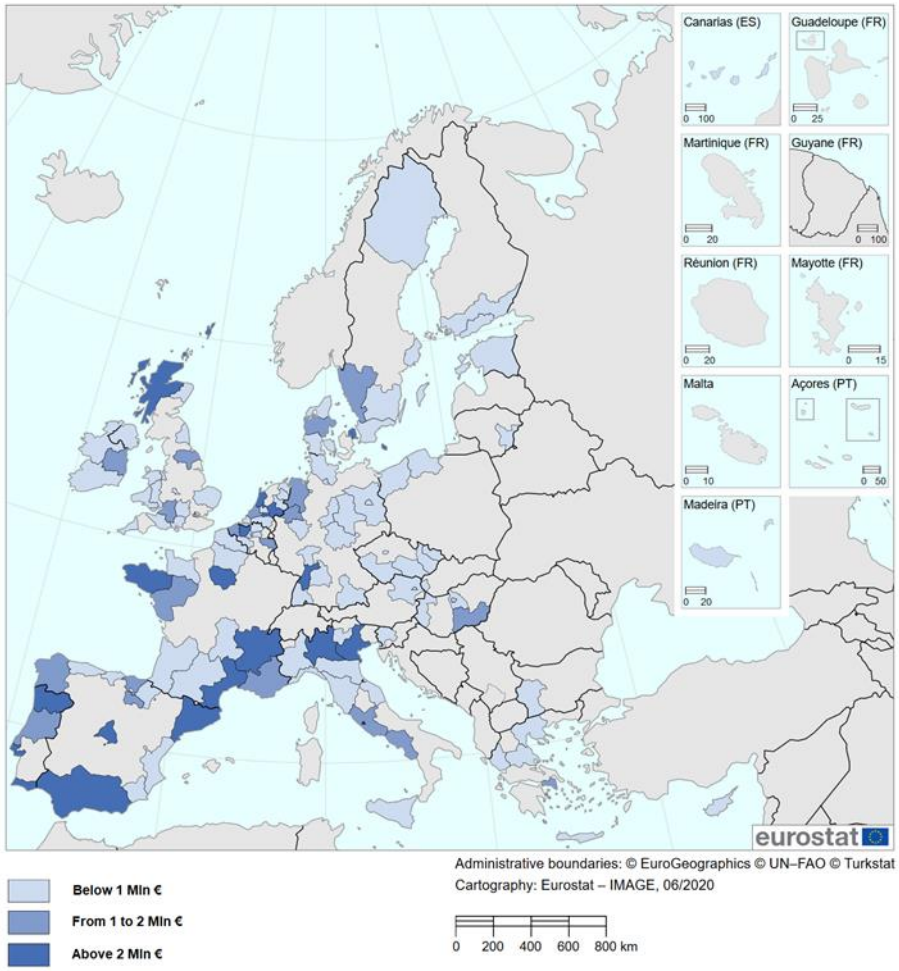
ERDF projects are a part of the instrument to implement EU Cohesion Policy. Funding is pre-allocated to a Region according to its level of development compared to the EU average. Hence, the first recipients of EU Cohesion Policy are southern and eastern European regions from EU 13 countries (Figure 9).

The Portuguese Centro and Norte Regions, Wales region (UK) and in a lesser extent Andalusia are among the first ERDF allocators implementing to a certain extent, as Horizon 2020 beneficiaries, direct synergies with this programme. In this respect. Concerning Central and eastern European regions, the Polish Lubieski and Hungarian Southern Great plain and western Transdanubia are among the most active.

Interreg projects: Signs of interregional collaboration in Blue biotechnology sector

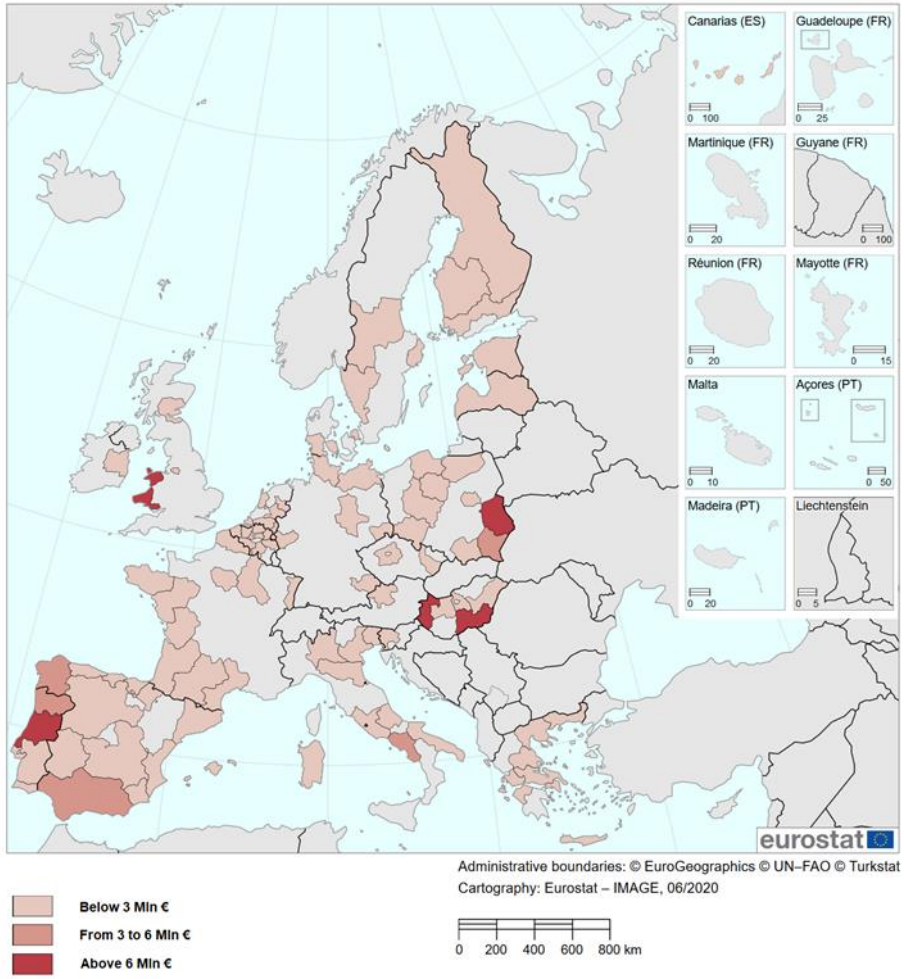
European Territorial Cooperation (ETC), better known as Interreg, is one of the two goals of cohesion policy and provides a framework for the implementation of joint actions and policy exchanges between national, regional and local actors from different Member States. Blue biotechnology is covered by at least eight Interreg projects in 2014-20 programming period, related established thematic such as Energy, Food security & safety, Biomedecine & Cosmetic, Environmental protection, new material and also to the support to overall blue biotech sector.

Figure 8 Horizon 2020 regional distribution related to Blue biotechnology (2014-Oct 2019)



Source: Own elaboration, Horizon 2020 Cordis database (as of October 2019)

Figure 9 ERDF regional distribution related to Blue biotechnology (2014-2018)



Source: : Own elaboration, ERDF beneficiaries' database described in Bachtrögler et al. (2020) (as of December 2018)

4.3 Largest projects and key stakeholders

Horizon 2020 largest projects: most are dedicated to Agri-food

The average Horizon 2020 contribution to Blue biotechnology projects (€1.7 million) states slightly below the overall programme average (€1.8 Million). That can be explained by the 25 SME phase 1 project received a lump sum of 50 000 €.

Among the 80 projects funded by Horizon 2020, Table 1 ranks the top ten projects according to the amount of EU contribution. Out of the 10 projects listed, six (Success, Primefish, Sabana, GenialG, and Seafoodtomorrow) are funded through a call dedicated to Blue Growth in the societal grand challenge related to 'food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy'. Two projects are funded a general call for projects launched by the BBI joint undertaking (Valuemag and Magnificent).

Table 1 The first 10 Horizon 2020 projects

Project Acronym (Pic)	Title	Area	EC Contrib (in Mln €)
GENIALG (727892)	GENetic diversity exploitation for Innovative macro-ALGal biorefinery	Energy	10.8
SABANA (727874)	Sustainable Algae Biorefinery for Agriculture and Aquaculture	Agri-food	8.8
SALTGAE (689785)	Demonstration project to prove the techno-economic feasibility of using algae to treat saline wastewater from the food industry.	Environment	8.3
ProFuture (862980)	Microalgae protein ingredients for the food and feed of the future	Agri-food	7.8
SEAFOODTOMORROW (773400)	Nutritious, safe and sustainable seafood for consumers of tomorrow	Agri-food	7
MacroFuels (654010)	Developing the next generation Macro-Algae based biofuels for transportation via advanced bio-refinery processes	Energy	6
MAGNIFICENT (745754)	Microalgae As a Green source for Nutritional Ingredients for Food/Feed and Ingredients for Cosmetics by cost-Effective New Technologies	Agri-food	5.3
SUCCESS (635188)	Strategic Use of Competitiveness towards Consolidating the Economic Sustainability of the European Seafood sector	Agri-food	5
PrimeFish (635761)	Developing Innovative Market Orientated Prediction Toolbox to Strengthen the Economic Sustainability and Competitiveness of European Seafood on Local and Global markets	Agri-food	5
VALUEMAG (745695)	Valuable Products from Algae Using New Magnetic Cultivation and Extraction Techniques	Energy, Agri-food, Biomedicine	4.8

Network analysis of Horizon 2020 funded Blue Biotech projects: What are the structuring collaborative projects? Which are the most central key organisations?

Network analysis provides structural parameters and graphs to describe a network and to measure the centrality (the 'power') of organisations or group of organisations forming the network. A network can be seen as a "set of actors and the ties among them" (Wasserman and Faust 1994).

More concretely, in the case of the analysis of Blue biotechnologies in Horizon 2020, a node represents an organisation receiving a grant and the tie a collaboration in one of the 80 blue biotech projects. Indicators can be calculated either at node or at network level. This type of analysis allows key players in a network to be revealed (Borgatti, 2006), those who are the more connected or those playing a particular role. The position and the role of each node are measured with centrality indicators helping to define its position and role in the network.

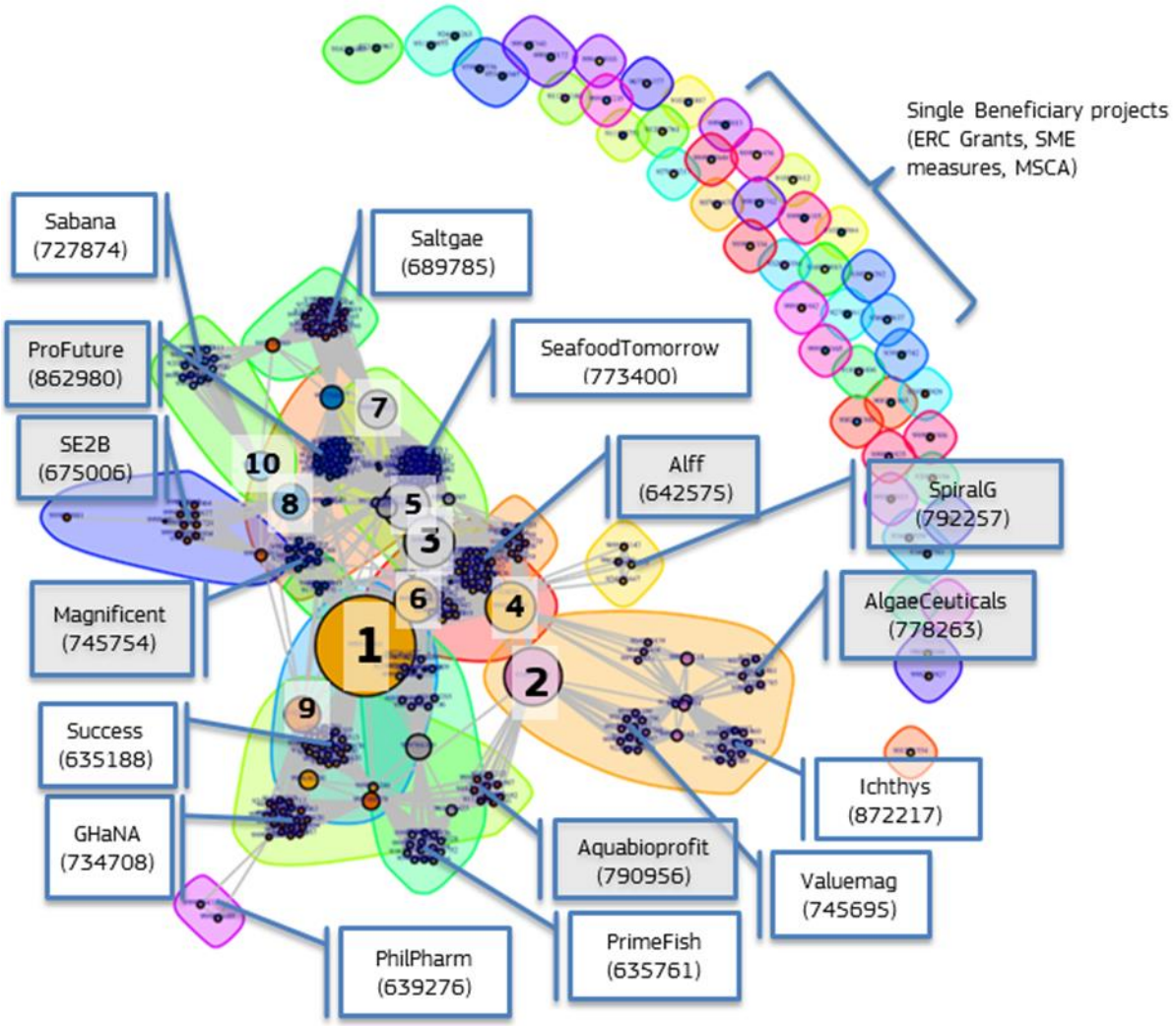
Figure 10 shows all the organisations receiving Grants for their participation in one or several projects related to Blue biotechnology. This type of graph aims at representing how organisations are behaving with others in a form that we can define as 'social' interactions. The groups of the nodes are representing

the collaborative projects with the most partners (between 25 and 30 out of the 80 projects in that field). However, it can be assumed that the structuring effect of Horizon 2020 on the European Research Area comes mainly from these projects.

Figure 100 indicates the names and the number of 17 projects identified behind the largest groups of nodes. The position of the groups is set according to the network proximity of organisations forming the group. The 'groups of groups' are forming clusters. For instance, projects like Success, GHaNA and Aquabiofit are in the cluster because some organisations have several ties with those projects.

At organisation level, the involvement in several projects increase the power of this organisation on the network. Two centrality indicators are calculated for each organisation). The first one is the number of ties connected to the organisation (Degree centrality) revealing the "popularity" of the organisation. An organisation participating in projects with high number of partners has a high score. The second indicator measures the strategic position of the organisation in the overall network (Betweenness centrality). It counts the number of times an organisation is on the shortest to connect the other organisations between themselves. The following Figure shows the 10 first organisations according to their Betweenness score. The organisations are represented by circles (nodes) with numbers inside corresponding to their ranking, the biggest is the node, the higher is the centrality score (the power on the network). These 10 organisations are detailed in table 2.

Figure 10 Collaboration network of organisations involved in the Horizon 2020 blue biotech projects



Source: Own elaboration (data: Horizon 2020 Cordis database as of October 2019, processing: R igraph package)

Table 2 provides the two indicators and ranks the organisations according to the Betweenness centrality indicator. For instance, the ranking shows an organisation can have a relatively low number of connections but with a strategic position in the network. That is the case for instance for French Vertech group or the German Karlsruher Institute for Technology.

Among the key stakeholders listed in

Table 2, eight out of ten organisations led by the Dutch Techcentre for life sciences are coming from the public sector (Public research organisations and universities). They are mostly based in northern Europe. Only two companies appear in the ranking Vertech group and Microphyt, both based in France.

Table 2 The 10 first strategic organisations involved in blue biotech projects

					Centrality measures	
	LEGAL_NAME (PIC id)	Project involvement	COUNTRY	ORG TYPE	degree	Betweenness
1	STICHTING WAGENINGEN RESEARCH (999547365)	Success, Macrofuels, Macro Cascade, Genialg, Magnificent	NL	Public Research organisation	642	11358
2	VERTECH GROUP (958250294)	ValueMag, Aquabioprofit, Waseabi	FR	Private company	158	6539
3	DANMARKS TEKNISKE UNIVERSITET (999990655)	Macro Cascade, SeafoodTomorrow, Waseabi	DK	University	311	5684
4	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS (999997930)	Alff, Algaee4A-B, GenialG, ChloroMito	FR	Public Research organisation	276	5649
5	UNIVERSITEIT GENT (999986096)	Alff, SeafoodTomorrow, ProFuture	BE	University	443	5345
6	THE SCOTTISH ASSOCIATION FOR MARINESCIENCE LBG (999738843)	Alff, MacroFuels,GenialG, Abacus	UK	Public Research organisation	335	4914
7	RISE RESEARCH INSTITUTES OF SWEDEN AB (999613422)	Saltgae, SeafoodTomorrow	SE	Public Research organisation	228	4299
8	WAGENINGEN UNIVERSITY (999981634)	SE2B, Magnificent, AlgCoustic, ProFuture	NL	University	309	4016
9	MICROPHYT (938267421)	Smile, GHaNA, Abacus	FR	Private company	170	4005
10	KARLSRUHER INSTITUT FUER TECHNOLOGIE (990797674)	Sabana, Abacus	DE	University	82	3184

Some examples of ERDF-funded operations

As stated in previous section, beneficiaries of ERDF funding are diverse, standing from public to private sector with nevertheless a majority of SME. The size and dimension of ERDF funding of Blue Biotechnology projects at regional level depends especially on two factors. The first is the availability of ERDF funding in Regions and the second the presence of a research ecosystem in the field of Blue biotechnology.

Two projects received more than seven million € ERDF funding, an amount comparable to the largest Horizon 2020 projects.

- The first (€7.4 million of ERDF contribution) is implemented in the region of Lubelskie (East Poland) for the establishment of a Research and Development Centre to develop industrial algae cultivation technology in temperate climates.
- The second (€7.2 million of ERDF contribution) is implemented by Swansea University in Wales. The project combines established expertise in algae conversion and hydrogen generation, with

emerging expertise in heat-to-electricity, CO2 capture, and chemical waste, and their conversion to high value added products.

The range of ERDF activities dedicated to Blue biotechnology is broad. The following list of examples of projects implemented since 2014 shows the wide range of topics covered:

- Energy production: Micro-algae biodiesel production integrated Bio refinery in Lazio region, Italy.
- Health: demonstration scale for the commercial production of two oilseed rich microalgae with numerous health benefits in Lisbon Region, Portugal.
- Agri-food: Scalable and self-controlled installation based on microalgae capable of handling liquid manure in Algarve region, Portugal or Exploitation of the marine algae as an ingredient in fish feed to improve the production and quality of aquaculture products in Greece.
- Environment and Climate change: Production of new micro algal strains/new products, bringing together CO2 capture capacity in Centro region, Portugal.
- Biomedicine: algae as nutrition component that stimulates the immune system in humans and animals in The Netherlands.
- Environmental remediation: treatment of mine acid water, valorisation of wastewater with microalgeas bacteria in Andalusia, Spain.
- New material: liquefaction pilot enabling the production of road binders from biomass such as microalgae, agro-industrial residues, pig slurry as alternative to the use of bitumen, Rhone-Alpes Region, France.

5 Indicators to monitor the European Blue biotechnology

Many European players are active within the R&I stage of the Blue biotechnology value chain, generating almost a third of the scientific publications in this field. However, a striking difference emerges when comparing scientific activity to trends in patent publication. Europe represents only 13% of patents filed in connection with new marine molecules, suggesting limited success in developing products from promising resources. In contrast, Japan and China appear far more active in patent publication than in scientific publication (ECORYS, 2014).

This chapter contains some reflections to identify indicators allowing a better monitoring of this sector across the EU. The absence of specific data and information dedicated to Blue biotechnology hampers the description and mapping the potential economic impact of the Blue biotechnology sector, in particular, at regional level. Despite the challenges, we propose a set of new specific indicators in order to establish the baseline of activities across the European regions that would allow to follow-up the progress through time.

5.1 Challenges in describing the Blue biotechnology with indicators

The Blue biotechnology sector is generally included in the larger sector of Biotechnology. While it is quite easy to define if a single organisation works with marine resources, and thus in the Blue biotechnology sector, this delimitation is rather impossible for a large group of organisations. However, this sector is unique amongst biotechnology sectors in terms of the way that it is defined. For example, whereas red (medical, health and pharmaceutical), green (agricultural), yellow (environmental) and white (industrial) biotechnologies are delineated on the basis of the processes they entail or the markets they serve, Blue biotechnology is the only biotechnology sub-sector to be defined by its source material (Collins et al, 2018). The interdisciplinary character of Blue biotechnology and the variety of applications of its products and services are contributing to the challenge of delimitation.

The main difficulty in the design of indicators related to Blue biotechnology is the same as for other emerging sectors. Existing Statistics look backward and focus often on well-established sectors or domains. In this context, the design of tailored indicators is necessary to give a periodic and accurate overview of what is happening in the field of Blue biotechnology at European level. Solutions to describe the sector, taking into account the difficulties to refer only to for-profit companies and to economic indicators, have been proposed. The Mediterranean science Commission[10] (CIESM), for example, proposed more "research-oriented indicators, such as revenues of universities and research centres from licences executed; start-ups created in the field of marine biotechnology; patent ownership; and the nationality of public and private actors engaged in R&D ventures" (OECD, 2017:11).

Information regarding the economic value, the knowledge produced through fundamental research but also through collaborative innovation projects need to be captured in order to provide a sound picture of this emerging domain and guide the policy intervention. As important as the knowledge delivered through scientific publications and patents, the characteristics of the ecosystem is of crucial importance. The key questions to address in order to monitor the Blue biotechnology sector could be the followings:

- What are the characteristics and evolution of private organisations (turn-over, employment, date of creation)?
- Where the organisations intervene in the value chain?
- What are the key stakeholders (Public and private)?
- What are the main R&I collaboration axes in Europe?

5.2 Proposal of new indicators

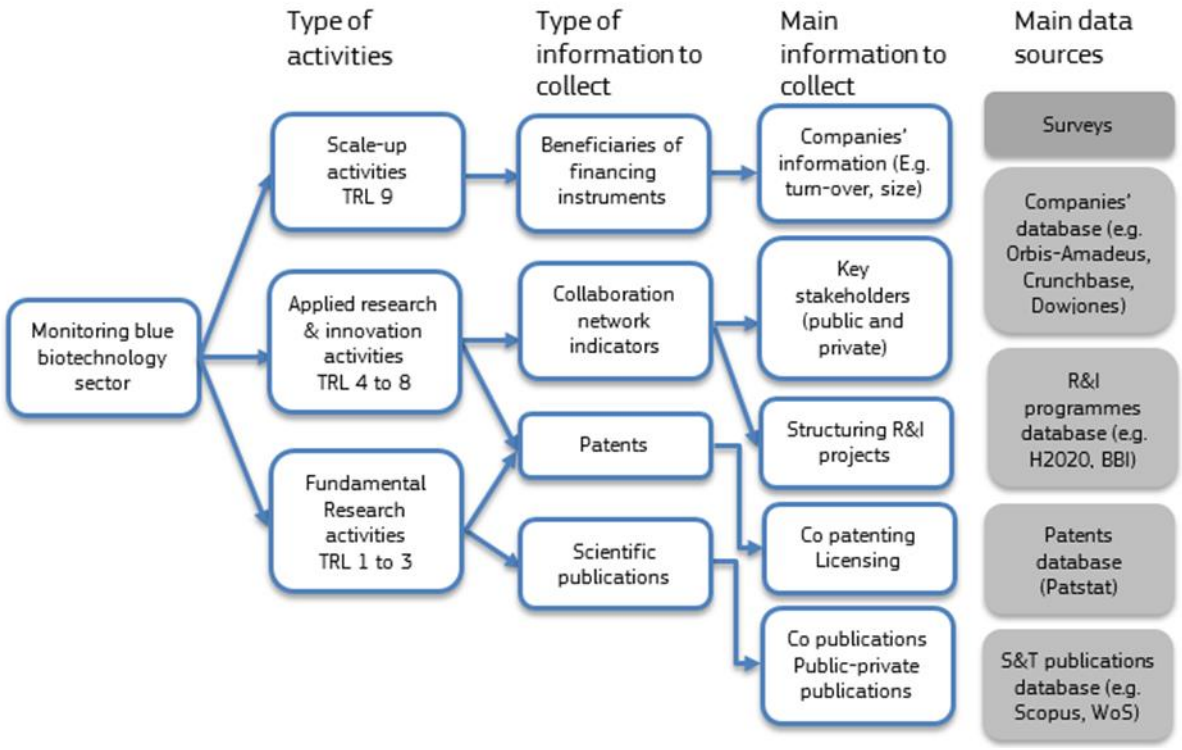
To be relevant and accurate, indicators need to be calculated from a delimited set of data. As explained in the previous section, difficulties come from the fact that the biotechnology sector does not have fixed statistical and methodological boundaries. Alternatively, data sets can be built from an existing corpus of knowledge (e.g. publications, patents) or projects (e.g. H2020, ERDF) with a selection process allowing the collection of the most relevant information about the sector. The use of a list of relevant keywords defining

[10] CIESM: Commission Internationale pour l'Exploration Scientifique de la Méditerranée (www.ciesm.org)

Blue biotechnology would be the most appropriate approach. Eventually, a mixed approach, combining statistics with an additional bottom-up desk research, including surveys or interviews to stakeholders within the sector would give policymakers sufficient information to design and implement support measures.

Figure 11 shows how activities to monitor can be linked to source of information and data. The objective would be twofold: first, indicators should provide information about the production of new knowledge and creation of economic value and second, they should also give an overview of the existing regional ecosystem (stakeholders involved in the Blue biotechnology sector).

Figure 11 Indicators and source of information to monitor the Blue biotechnology sector



Source: Own elaboration

Despite the complexity of finding indicators to describe the sector, there seems to be potential for monitoring relevant regional activities in the sector. In line with the regional typology of Blue biotechnology in regions a set of indicators of indicators can be proposed. Complementing statistic indicators, the relevant data could be gathered through a periodic survey to relevant stakeholders (e.g. regional innovation agencies, science competence centres in the field of Blue biotechnology) or through an on-going database on regional projects, infrastructures and networks. Both measures to gather data could also be combined.

Table 3 Proposition of indicators related to Blue biotechnology sector

Indicator Group	Indicator	Possible data source	Practical issues
Natural Resources	Amount and value of aquaculture production	EU Bioeconomy Monitoring System (EC) FAO	To be collected annually Might be extended towards microalgae and macroalgae The EU-MAP latest regulation includes the collection of seaweed. On a voluntary basis, MS are asked to report microalgae as well.
Policy commitment	No. of dedicated research or development strategies tackling Blue biotechnology (aquaculture, algae, aquatic resources, Marine resources)	Survey to relevant research organisations asking about the existence of relevant strategies.	Organise a conference on Blue biotechnology that will help to identify and bring together relevant strategies and present a good starting point for a survey.
Science and Technology	No. of dedicated research Blue biotechnology projects per year (working with marine/aquatic biomass)	A possible data source would be Funding programme statistics. Survey to relevant research organisations about their projects (supported by the EU).	Blue Economy/ Biotechnology projects should be described with a specific code, this would make data collection easier. Without code, data needs to be collected manually
Business activity	No. of companies working with Blue biotechnology (Biotechnology: sub-category: working with marine/aquatic biomass)	Scientific, Technical and Economic Committee for Fisheries (STECF): Economic Report of the EU Aquaculture sector For now, only available in some countries, as national initiatives to measure the blue economy (Ireland, Portugal) No statistical data available, requires a definition of the sector and unified data collection A possible data source could be existing (Blue) Biotechnology networks, associations, cluster etc.	Data should be collected via a survey to members of the above-mentioned organisations. As the survey will be resource-intensive it shall be updated only every 2-3 years.
Social impact	Employment in Blue biotechnology companies	FAO JRC: Scientific, Technical and Economic Committee for Fisheries (STECF): Economic Report of the EU Aquaculture sector	To be collected annually Currently, STECF shows some data gaps that might be solved. Might be extended towards microalgae and microalgae

6 Case studies

For the purpose of this report, three case studies of implementation of Blue biotechnology R&I projects at regional level have been analysed in-depth with a view to the smart specialisation processes across Europe and aim at gaining a better understanding of different strategic approaches and regional profiles across the European Sea Basins. The three cases represent the Atlantic Sea Basin (Scotland), the Baltic Sea Basin (Schleswig-Holstein) and the Central Mediterranean (Slovenia). Numerous inputs to Blue biotechnology research and innovation in these areas come from Smart Specialisation strategies and from cooperation projects and are highlighted under each case.

6.1 An overview of the Blue biotechnology area in Scotland

Scotland is one of Europe's leading regions with regards to Blue biotechnology. The Blue biotechnology builds upon a rich marine life in the waters around Scotland and a relatively large aquaculture sector. It forms, with the production of macro and micro-algae the basis for the Blue biotechnology sector in Scotland. These activities are supported by various policy documents and strategies and actively involve numerous stakeholders that contribute to the development of the Blue biotechnology sector in Scotland that is characterised by an integrated approach to developing Blue biotechnology in the region.

The Scottish **Research and Innovation Strategy for Smart Specialisation (RIS3)** was developed for the 2014-2020 ERDF funding period. Though Blue biotechnology is not explicitly addressed, the document mentions certain related activities in the priority areas of Life Sciences and Marine Energy, which are encouraging a further research and innovative activities in the fishery sector and fish processing industries.

The Scottish Government acknowledged the importance of the emerging Blue biotechnology sector in its "**Aquaculture Science & Research Strategy**" (Marine Scotland 2014), which aims to strengthen coordination of research activities in the aquaculture sector. The document lists some key areas to foster the Blue biotechnology sector in Scotland such as yielding of high-value compounds, improving skills and training of next generation marine biotechnologists, and optimising micro-algal cultivation systems for bio-refinery.

Table 4 Main Scottish stakeholders in Blue biotechnology

The Industrial Biotechnology Innovation Centre (IBioIC)	The centre was established in 2014 following the national plan for industrial biotechnology with the aim to stimulate growth of the regional industrial biotechnology. It connects industrial members with specialist individuals whose expertise covers all areas of industrial biotechnology through its Technical Network. The centre provides scale-up facilities, talent development, funding and networking opportunities for biotechnology
The Scottish Aquaculture Innovation Centre	The centre represents one of the eight innovation centres introduced by the Scottish Government to drive growth in areas of key economic and social importance for the region. It connects industry with academia to encourage collaboration on priority issues, share insights and knowledge gleaned with the wider sector, and boost the interest of new generations for the sector as well as help further development of potentials of those already working within it.
Scottish Association of Marine Science (SAMS)	Located at the European Marine Science Park in Oban, this research centre is a unique science park in Europe dedicated to Blue Growth and Marine Sciences and represents a home of a growing economic cluster encouraging exchange between businesses, policy makers and science and forms the cluster that hosts more than 100 scientists from different marine fields working in more than 12 organisations

The Scottish Aquaculture Research Forum	The forum gathers representatives from the aquaculture industry, government, fishermen and environmental NGOs has been established to implement the regional aquaculture science and research strategy (see above). Its main objectives are to enhance the understanding through the dissemination of research results and to promote, encourage and support scientific research.
Marine Alliance for Science and Technology for Scotland	The Alliance promotes marine research in and about Scotland and represents approximately 700 researchers. Although most of the research themes do not address Blue biotechnology explicitly, they provide a solid based on which the sector could further develop, e.g. building research networks for aquaculture, biogeochemistry and technology and sensors.

Interregional Cooperation on Blue biotechnology

The Scottish Blue biotechnology research infrastructures, networks and clusters are involved in European collaborative projects and actions. With the important weight given to research in Scottish Blue biotechnology strategic documents, the cooperation of the regional stakeholders is not limited to neighbouring partners in the Atlantic or North Sea areas, but targets also active cooperation across Europe and beyond. The European Marine Biological Resource Centre (EMBRC), co-funded through the support of the Horizon 2020 programme, is one of the cooperation networks in which Scottish stakeholders are actively engaged. The aforementioned research centres, networks and clusters have been during the past years actively engaged in numerous projects funded and co-financed through various regional (SAMS) and the EU sources (H2020 and ESIF) that directly support the Blue biotechnology sector in the region and the numbers of projects have been steadily growing since 2006 (Marine Scotland, 2014). The project database established for this research focusing on 2014-2020 projects (see section 4) identified seven large European projects with active involvement of Scottish partners, namely EMBRIC, GENIALG, FUCODERM, MACROFUELS, ALFF, AQUAVITEA, and ABACUS, with a total value of € 42.3 million of EU-investments with different research and innovation focuses and different stages of the respective value chains. While most of these projects focus on discovering possibilities of marine life as resource for products and processes, the project FUCODERM (involving a company Glycomar from the Europe Marine Science Park) focuses the later stages of the value chain through a concrete product development, i.e. on developing an algae-based cream for skin problems. Through SAMS as an associate member of the Submariner network, Scotland participates also in the Baltic Sea Blue biotechnology ALLIANCE.

6.2 An overview of the Blue biotechnology area in Schleswig-Holstein

The geographical situation between the North Sea and the Baltic Sea endows Schleswig-Holstein with important assets to use and exploit marine resources. Traditionally marine environment research is very strong in the region.

Schleswig-Holstein is member of the Baltic Sea Submariner Network. The network has published in 2013 a Baltic strategy for Marine Biotechnology (**"Masterplan Marine Biotechnology Schleswig-Holstein - A Regional Development Strategy"**[11]. The strategic document analysed the situation and developed measures in nine different value chains of marine biotechnology: pharmaceuticals, cosmetics, nutrition, aquaculture, energy, environment, diagnostics, industrial processes/process engineering and chemistry.

In 2014, the Schleswig-Holstein region presented a **Regional Strategy for Sustainable Aquaculture**[12] aiming to develop aquaculture with a consistent and holistic application of clear sustainability criteria and,

[11] http://www.submariner-project.eu/index.php?option=com_content&view=article&id=148:masterplan-marine-biotechnology-schleswig-holstein-germany-&catid=55&Itemid=395

[12] Ministerium für Energiewende, Landwirtschaft, Umwelt und ländliche Räume (2014). Strategie zur Entwicklung einer nachhaltigen Aquakultur in Schleswig-Holstein. Kiel.

where possible, increase the production of fish, bivalve molluscs and crustaceans. To support its implementation, the region hosts the national competence centre in research on marine aquaculture with a strong scientific basis. Furthermore, the **regional RIS3 Strategy** serves as the basis for the regional ERDF Programme 2014-2020, dedicating funding to marine biotechnology as a key technology and a regional area of opportunity in which different specialist areas interconnect. Marine Biotechnology has crucial links to regional competence areas to be further developed, namely through the research and innovation activities in life sciences, agri-food and maritime economy.

Table 5 Main regional stakeholders

GEOMAR Centre for Marine Biotechnology (GEOMAR-Biotech)	Based in Kiel, GEOMAR is a research platform for marine natural product research and marine biotechnology with a focus on identification, production and promotion of new natural products from marine microbial sources and the investigation of their biological activities and ecological function.
The Kiel Marine Science (KMS)	Centre for Interdisciplinary Marine Science at Kiel University. As one of four priority areas at the University, KMS is the organizational unit of the marine researchers organised through 41 research groups in seven faculties and 18 institutes. KMS research groups cover expertise from areas such as climate research, coastal research, physical chemistry, botany, microbiology, mathematics and computer science, economics as well as law and social sciences.
The Fraunhofer Research Institute for Marine Biotechnology (EMB)	Based in Lübeck, the institute has put its focus on the isolation and utilisation stem cells of fish, on the use of fish cells as alternative of fish meal and on integrative aquaculture, but does not work on marine natural products.
Research Facility Marine Aquaculture (Gesellschaft für Marine Aquakultur mbH, GMA)	GMA runs their own Aquaculture Research- and Development Facilities (RAS), supporting the conduction of both external and internal aquaculture research and development projects. Another core area is the transfer of aquaculture knowledge and technology for both seawater and brackish water.
The National Competence Centre for Marine Aquaculture	Project of the Christian-Albrechts-University including national and international networking, promoting establishing of aquaculture companies in the region, development of environmentally friendly aquaculture systems, building research cooperation.
The Competence Network for Aquaculture (KNAQ)	KNAQ is the accompanying network to the Competence Centre for Aquaculture and has been set up by the regional Chamber of Agriculture of Schleswig-Holstein

Structuring activities to foster Interregional Cooperation on Blue biotechnology

Numerous research projects in the region are being implemented through a combined support of regional, national and EU funding, and coordinated through the Marine Biotechnology Masterplan. The relevant research partners, mainly Kiel University, the Centre for Marine Biotechnology (GEOMAR-Biotech) and Fraunhofer, are involved in many EU projects. Among the most important activities implemented at regional (Länder) level, federal or European level, the three following ones are worth to be mentioned:

- The Baltic Submariner Network
  The network established in 2013 has developed a transnational hub in the Baltic area for promoting sustainable and innovative uses of marine resources. Submariner serves as an important driver of projects in the blue growth sectors in guiding the strategic analysis and planning in the field of marine biotechnology. The roadmap based on the findings of a comprehensive assessment of the potential for innovative and sustainable uses of marine resources in the Baltic Sea Region proposed numerous actions grouped thematically into the topics and strategic action fields.

- The "Baltic Blue biotechnology Alliance"
  The project gathers relevant partners from the Blue biotechnology sector tackling development issues of the blue biotech sector in the region in order to promote a systematic pan-Baltic

approach. The project started in 2016 as part of the 2014-2020 Interreg Programme with a budget of € 3.7 million and aimed at reaching the critical mass through systematic cooperation to pool national resources and expertise. Its lead partner is GEOMAR from Schleswig-Holstein and consortium partners come from research organizations, biotech hubs, business parks, Submariner Network, and companies from the Baltic Sea region and include associated partners from Scotland, France and Portugal, which increase the European added-value of the project.

- The flagship project Bioeconomy on Marine Sites (BaMS)
  The project is coordinated by the Christian-Albrechts-University of Kiel (CAU) and funded by the Federal Ministry of Education and Research (BMBF) over a period of five years with up to 20 million euros. The aim is to develop an innovation area in northern Germany for the blue bioeconomy, in which new processes are implemented and sustainable concepts for a comprehensive circular economy are promoted, which include marine biological resources such as fish, mussels or algae. The "Bioeconomy on Marine Locations" project also strengthens the Kiel Marine Science (KMS) university research focus at Kiel University.

6.3 An overview of the Blue biotechnology area in Slovenia (and the Adriatic-Ionian sea basin)

The Interreg ADRION Programme invests in regional innovation systems, cultural and natural heritage, environmental resilience, sustainable transport and mobility as well as capacity building in the Adriatic and Ionian region. As a transnational cooperation programme, it focuses on exchanging transnational experiences and addresses the challenges in the region supporting the governance of the European Strategy for Adriatic-Ionian Region[13] (EUSAIR) and facilitates cooperation among partners. The EUSAIR is a macro-regional strategy that aims to coordinate activities and governance processes to enhance cooperation on areas of common interest. Blue Growth is one of the four pillars of the strategy that aims to promote innovation and business opportunities specifically in the blue economy sector and is further divided into three priority areas, namely blue technologies; fisheries and aquaculture; and maritime and marine governance and services.

Though Blue biotechnology as such is not explicitly mentioned in the **Slovenian Smart Specialisation Strategy**[14], three priorities are considering related activities, especially the one named "Networks for the Transition to Circular Economy" is focusing research and innovation activities for sustainable biomass transformation and production of new bio-based materials, technologies for use of secondary and raw-materials and reuse of waste.

1. A first Priority Area "Natural and Traditional Resources for the Future" includes marine resources as potential element in the three action lines regarding the transition towards a circular economy:
   a. Technologies for sustainable biomass transformation and new bio-based materials;
   b. Technologies for use of secondary and raw-materials and reuse of waste; and
   c. Production of energy based on alternative sources.
2. A second priority area that includes marine products and their processing is sustainable food production with the action line on sustainable production and processing of food products into functional foods and
3. A third priority Health/Medicine with research and innovation activities related to biotech medical applications and quality of life.

[13] https://www.adriatic-ionian.eu/
[14] Slovenian Smart Specialisation Strategy S4. 2015.

The country's national RIS3 strategy is further elaborated in action plans and roadmaps and further fine-tuning of the prioritisation is assured through the so-called Strategic Research and Innovation Partnerships (SRIPs) that engage quadruple helix stakeholders in the process of further specialisation on innovative products and services on a permanent and continuous basis. The Roadmap for circular economy as well as the Action Plans for strategic research and innovation activities for the transition to circular economy, sustainable food production and health care mention the need for further research on the use of marine life and on developing technologies in the fields of biomass processing and the development of new bio-based materials. This approach is being strengthened and supported by a recent innovative large-scale demonstration programme integrating the governance and the whole society towards circular green economy called "Decarbonising Slovenia" coordinated by the Slovenian Government, encompassing the entire public administration procurement and with the close cooperation of the EIT Climate-KIC and EIT Raw Materials[15].

Slovenia hosts several public and private research institutes relevant also for the Blue biotechnology that have been actively involved in the smart specialisation process and its prioritisation endeavours. The **National Institute of Biology (NIB)** and its department **Marine Biological Station Piran** is one of the very active institutes in the Adriatic area and beyond and focuses on developmental and applicable research in the fields of biotechnology, biomedicine and system biology. The institute's current research covers the development of cultivation technologies for high scale production of bio-active compounds from algae and cyanobacteria, and purity controls of biotechnological products. These activities are directly related to enhancing Blue biotechnology in the broader region. The cooperation networks of research institutes and companies formed through the implementation the smart specialisation strategy allows the sharing knowledge on the extraction of different compounds of various marine organisms and serve as platforms for discussion of the applicability of these compounds in different products. Such networks provide an added-value against individual research activities to further develop the field in the region and beyond. Some networks have their origin in the region but cover also other countries and other parts of Europe and the southern Mediterranean coast. A database elaborated for the reporting on the blue biotech projects in the Mediterranean Sea basin includes 21 EU-funded blue biotech related projects and though most of these projects focus on the Western Mediterranean. There are also some projects with a focus on the Central-Eastern Mediterranean and in particular in the Adriatic region. Some relevant blue biotech oriented projects in the Adriatic-Ionian area financed by a variety of programmes are as follows:

- **BLUE BOOST**: a cooperation project financed through the Interreg ADRION programme focuses on enhancing the innovation potential of the triple-helix of traditional and emerging Blue growth sectors' clusters in the Adriatic-Ionian area through an open source/knowledge sharing and community-based approach;
- **MEDAlgae**: an algae-focused project led by Cyprus and funded by ENPI;
- **MEWLFE**: a project supported through the LIFE programme, focusing on the cultivating microalgae biomass from olive oil wastewater using phototrophic-heterotrophic environments;
- **Blue Education for Sustainable Management of Aquatic Resources**: an EMFF project financed through EASME;
- **GoJelly**[16], a Horizon 2020 supported project involving 16 partner organizations from nine countries with the participation of the Slovene National Institute of Biology (NIB) and the Marine Biological Station in the blue biotechnological studies. The project aims to develop, test and promote gelatinous solutions to the micro-plastic pollution in the seas.

[15] EIT Climate-KIC and EIT Raw Materials 2019.
[16] https://gojelly.eu

7 Conclusions

Blue biotechnology is a multi-disciplinary, knowledge and capital-intensive technology, which enables great potential for innovation. Related innovation applications can be seen in several supply chain processes including marine biomass and biofuels. In the EU, aquaculture, algae and micro-algae are representative domains of Blue biotechnology.

A marked localisation of economic activity along with the particular entrepreneurial configuration, characterise the Blue biotechnology activity in the EU. For example, aquaculture production is mostly concentrated in four Member States: Spain (21%), France (15%), Italy (14%) and Greece (10%), making up 60% of the sales volume. The significant number of enterprises (estimated to be 12 500), are mostly micro-enterprises which employ less than 10 employees each.

Yet, a premature stage of research is present in the Macro and Microalgae sectors, conditioning the innovation scaling-up into the markets. Innovative applications appear in human nutrition, animal feed, fuel source, fibres, co-digestion substrate, source of fatty acids, compost and organic fertilizers, antioxidants, pigments, and disease control agents. In order to improve the research activity and related outcomes, availability of data remains a fundamental element of consideration and improvement.

The analysis of Smart Specialisation strategies reveals that Blue biotechnology in EU regions represents an opportunity to increase competitiveness advantages. Territorially, although Blue biotechnology offers major potential in coastal regions, it is observed that non-coastal territories specialise in micro-algae and development of bioactive compounds from marine bio-resources.

The territorial and socio-economic diversity of EU regions reflect how regions specialise in the domain of Blue biotechnology. Accordingly, five different types of regional specialisation profiles were identified:

(i) Regions with a research driven bio-economy profile,

(ii) Regions with a natural resources and heritage driven bio-economy profile,

(iii) Regions with a primary value chain bio-economy profile,

(iv) Regions with an industrial biotech profile, and

(v) Regions with an integrated and advanced blue bio-economy profile.

In terms of funding, the estimations show that since 2014, the EU Blue biotechnology sector benefits of around €262 million channelled through the European Regional Development Fund (ERDF) and Horizon 2020 fund. The supported areas include Agri-food (aquaculture, food processing), Energy (bio-refinery, hydrogen production), Environment protection (bioremediation, wastewater treatment), Biomedicine & Cosmetic, Fundamental research (definition, process).

Economic activity and progress of blue bio-economy sector can be improved thanks to the establishment and improvement of monitoring mechanisms. To this respect, indicators were identified aiming at contributing to reduce related gaps. These indicators are grouped in five different categories addressing natural resources, policy, science and technology, business activity, and social impact. This identification includes also possible data and sources and suggestion on how to collect related information and data.

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